...nd Related Land Resources Plan for the State of Montana

THE FRAMEWORK REPORT

VOLUME ONE

Montana Department of Natural Resources and Conservation
water resources division

Cover photo of the Mission Mountains by Bill Browning. Courtesy of the Montana Chamber of Commerce and Montana Department of Fish and Game.

A Comprehensive Water and Related Land Resources Plan for the State of Montana

THE FRAMEWORK REPORT

VOLUME ONE

Part One. Planning the Wise Use of Montana's Water

Part Two. Water and Related Land Resources of Montana

The State of Montana	Thomas L. Judge Governor
The Montana Department of Natural Resources and Conservation	Gary J. Wicks Director
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OCTOBER 1976

HELENA, MONTANA

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FOREWORD

The Framework Report, is one element in the continuing program of planning for Montana's water and related land resources. The overall planning program is being conducted by the Department of Natural Resources and Conservation (DNRC) in cooperation with other state, federal, and local organizations and private groups for the use of persons in the public and private sectors.

The Framework Report, being prepared in three volumes, is not intended to fulfill all the objectives of Montana's complete long-range planning program. Rather, it will present a generalized state-wide overview of Montana's present water and related land resources situation, including discussions of present water use, problems and needs, trends and opportunities, legal and institutional considerations, and needed action. The report will define the process of in-basin plan formulation and set the stage for the early study of problem areas. It is comprehensive in that the entire geographical area of the state and all anticipated types of water uses have been considered in its preparation.

Certain data, assumptions, and procedures were adopted from other related studies. Much of the data presented, however, has never before been published and is the result of several years' work in the water planning field.

Volume One, "Part One" identifies the legal authority for river basin planning in Montana, discusses previous state-wide planning activities, describes the present status of the water plan and regional water planning efforts, and presents the planning methodology and a statement about the final plan. "Part Two" describes the water and related land resources of Montana.

Volume Two will discuss present water and related resource uses, make projections of future use, and discuss existing problems and future needs within eleven functional areas including municipal, industrial, rural domestic, livestock, irrigation, and energy water use; water quality; fish and wildlife; outdoor recreation; flood damage reduction; and related land use.

Volume Three, "Part One" will address the many legal and institutional considerations of water planning in Montana and, in "Part Two," will draw a number of general conclusions and make recommendations based on the material presented in the previous volumes.

The Department recognizes the efforts both of those within the Water Resources Division and of others who have contributed to preparing **The Framework Report:**

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INTRODUCTION

PURPOSES

Montana's water and related land resources can provide current and future generations with a quality environment in which to live, work, and relax. It is the state's concern that resources be managed in an orderly manner to enhance this quality environment, and it is largely through resource planning that this can be accomplished.

In determining the optimum utilization of water resources, it is necessary to understand the current water resource situation, the land uses that affect the quantity and quality of the water, and the effect of water availability on potential land use. The general purpose of this and subsequent framework study publications is to provide necessary background information, as well as a broad conceptual framework for the development of an overall plan for the efficient utilization of the water and related land resources of the state of Montana. It is anticipated that this framework study will act as a guide to federal, state, local, and private entities engaged in the planning, design, construction, and operation of resource development projects in Montana and in studying the future use of all Montana's water and related land resources.

The specific purposes for which **The Framework Report** was written include:

1. To explain state-wide water planning in Montana, including a discussion of the criteria and methodology for water planning and a history of past procedures in state water planning activities.

2. To define the overall, ongoing, and "final" objectives of Montana's State Water Plan.

3. To present Montana's water and related land resources, including a discussion of consumptive and non-consumptive uses of water.

4. To evaluate current water management, with specific attention to those problem areas where solutions are urgently needed and informational gaps exist.

5. To identify both the more detailed studies required to increase knowledge of Montana's resource base and the specific project studies required for the most efficient use of the state's resources.

6. To develop a process for future water planning and the undertaking of additional data collection, research, river basin plans, and special studies.

7. To discuss the possible need for changes in laws, policies, and administrative arrangements.

It is anticipated that **The Framework Report** can be used in two contexts. First, it can serve as a reference for legislators, government officials, individuals, and organizations interested in existing conditions governing the availability, use, and management of water within the state. Second, it can be used in comprehensive river basin planning as a guide regarding approaches to solving short- and long-term water problems.

INVOLVED AGENCIES AND GROUPS

Many state, federal, and private agencies and groups have become an integral part of the state water planning program and will, as water and related land resource planning continues, become more and more involved in the development of alternatives and the making of decisions. Listed below are many of these agencies and groups.

1. **United States Agencies:**
   - Army Corps of Engineers
   - Dept. of Agriculture
     - Agricultural Research Service
     - Agricultural Stabilization and Conservation Service
     - Economic Research Service
     - Farmers' Home Administration
     - Forest Service
     - Soil Conservation Service
     - Statistical Reporting Service
   - Dept. of Commerce
     - Bureau of Census
     - National Weather Service
   - Dept. of Housing and Urban Development
   - Dept. of Interior
     - Bonneville Power Administration
     - Bureau of Indian Affairs
     - Bureau of Land Management
     - Bureau of Mines and Geology
     - Bureau of Outdoor Recreation
     - Bureau of Reclamation
     - Fish and Wildlife Service
     - Geological Survey
     - National Park Service
     - Office of Water Research and Technology
   - Dept. of Transportation
   - Environmental Protection Agency
   - Federal Power Commission
   - National Marine Fisheries Service

2. **River Basin Commissions:**
   - Missouri River Basin Commission
   - Pacific Northwest River Basins Commission
   - Yellowstone River Compact Commission

3. **Montana Agencies:**
   - Bureau of Mines and Geology
   - Dept. of Agriculture
   - Dept. of Community Affairs
   - Dept. of Fish and Game
   - Dept. of Health and Environmental Sciences
   - Dept. of Highways
   - Dept. of Natural Resources and Conservation
     - Conservation Districts Division
     - Energy Planning Division
     - Forestry Division
     - Oil and Gas Conservation Division
     - Water Resources Division
   - Dept. of State Lands
   - Montana College of Mineral Science and Technology
   - Montana State University
   - University of Montana

4. **Other Groups:**
   - Beartooth Resource Conservation and Development (RC&D) Project
   - Bitter Root RC&D Project
   - Conservation Districts
   - County Commissioners
   - County Planning Offices
   - Economic Development Association of Eastern Montana
   - Grazing Districts
   - Headwaters RC&D Project
   - Irrigation Districts
   - Montana Stockgrowers Association
   - Montana Water Development Association
   - Montana Woolgrowers Association
   - Regional Planning Association of Western Montana
   - South-Central Montana Development Federation
   - Tribal Councils
   - Water Users Associations

PART ONE

PLANNING THE WISE USE OF MONTANA'S WATER

A HISTORY OF WATER PLANNING IN MONTANA

STATE AGENCY PLANNING

Although the Montana Water Resources Act of 1967 was the first specific legislation aimed at developing a comprehensive water plan for Montana, several activities previously carried out by state agencies were based on some of the same objectives and accomplished some planning and development.

Initial Planning Efforts

One of the first water planning efforts in Montana was accomplished by the Montana Irrigation Commission, which produced plans for irrigation development by county in the period from 1919 to 1921.

An important factor in supplying background data on water development was the inauguration of the Water Resources Survey under the State Engineer in 1934. Without this survey, the state would have virtually no reliable information concerning Montana's water use on irrigated land and no inventory of water rights for the protection of individuals in the state.

Creation of the State Water Conservation Board in 1934 resulted in extensive planning of individual projects; this effort, too, was irrigation oriented and, as a result of federal agency demands, was aimed toward providing economic relief during the depression of the thirties.

Section 89-105, R.C.M. 1947, enacted in 1933, empowered the State Water Conservation Board "... to make such investigations as may be necessary to plan and carry out a comprehensive state-wide program of water conservation." Through the years the Board accumulated a large amount of background data and experience fundamental to any planning effort. Little was accomplished toward comprehensive water planning unrelated to project development, however, until 1967.

The Montana Water Resources Act of 1967: Legal Authority for the State Water Plan

In passing the Montana Water Resources Act of 1967, the Montana Legislature assigned the duties of the State Water Conservation Board, Carey Land Act Board, and State Engineer to the Montana Water Resources Board (which later became the Water Resources Division of the DNRC) and mandated preparation of a state water plan. The necessity and policy upon which this action was taken are clearly stated in Section 89-101.2, R.C.M. 1947.

It is hereby declared that:

(1) The general welfare of the people of Montana, in view of the state's population growth and expanding economy, requires that water resources of the state be put to optimum beneficial use and not wasted.

(2) The public policy of the state is to promote the conservation, development and beneficial use of the state's water resources to secure maximum economic and social prosperity for its citizens.

(3) The state, in the exercise of its sovereign power, acting through the department of natural resources and conservation shall co-ordinate the development and use of the water resources of the state so as to effect full utilization, conservation and protection of its water resources.

(4) The development and utilization of water resources, and the efficient, economic distribution thereof, are vital to the people in order to protect existing uses and to assure adequate future supplies for domestic, industrial, agricultural and other beneficial uses.

(5) The water resources of the state must be protected and conserved to assure adequate supplies for public recreational purposes and for the conservation of wildlife and aquatic life.

(6) The public interest requires the construction, operation and maintenance of a system of works for the conservation, development, storage, distribution and utilization of water, which construction, operation and maintenance is a single

object and is in all respects for the welfare and benefit of the people of the state.

(7) It is necessary to co-ordinate local, state and federal water resource development and utilization plans and projects through a single agency of state government, the department of natural resources and conservation.

(8) The greatest economic benefit to the people of Montana can be secured only by the sound co-ordination of development and utilization of water resources with the development and utilization of all other resources of the state.

(9) To achieve these objectives, and to protect the waters of Montana from diversion to other areas of the nation, it is essential that a comprehensive, co-ordinated multiple-use water resource plan be progressively formulated, to be known as the 'state water plan.'

In order to fulfill the intent of the Act as quoted above, the Legislature further spelled out the procedure for development and implementation of the State Water Plan in Section 89-132.1 of the Act:

The department shall:

(1) Gather from any source reliable information relating to Montana's water resources, and prepare therefrom a continuing comprehensive inventory of the water resources of the state. In preparing this inventory, the department may conduct studies, adopt studies made by other competent water resource groups including federal, regional, state or private agencies, perform research or employ other competent agencies to perform research on a contract basis, and hold public hearings in affected areas at which all interested parties shall be given an opportunity to appear.

(2) Formulate and with the approval of the board [of natural resources and conservation], adopt, and from time to time amend, extend or add to, a comprehensive, co-ordinated multiple-use water resources plan, known as the 'state water plan.' The state water plan may be formulated and adopted in sections, these sections corresponding with hydrologic divisions of the state. The state water plan shall set out a progressive program for the conservation, development and utilization of the state's water resources, [and] propose the most effective means by which these water resources may be applied for the benefit of the people, with due consideration of alternative uses and combinations of uses. Before adoption of the state water plan, or any section thereof, the department shall hold public hearings in the state, or in an area of the state encompassed by a section thereof if adoption of a section is proposed. Notice of the hearing or hearings shall be published for two (2) consecutive weeks in a newspaper of general county circulation in each county encompassed by the proposed plan or section thereof at least thirty (30) days prior to the hearing.

(3) Submit to each general session of the legislature the state water plan or any section thereof or amendments, additions or revisions thereto which the department has formulated and adopted.

(4) Prepare a continuing inventory of the ground-water resources of the state. The ground-water inventory shall be included in the comprehensive water resources inventory described in subsection (1) above, but shall be a separate component thereof.

(5) Publish the comprehensive inventory, the state water plan, the ground-water inventory, or any part of each, and the department may assess and collect a reasonable charge for these publications.

(6) The board may adopt rules necessary to effect the purposes of this act.

Thus, Section 89-132.1 relates the scope and objectives of the State Water Plan; as originally passed by the legislature, the Act designated the Montana Water Resources Board as the state agency responsible for the development of the plan. Early in 1968, the Board organized a planning staff which reviewed the mandate of the Montana Water Resources Act and decided that the State Water Plan should be developed in four phases (discussed below under "Planning Procedure"). The first phase, the inventory, was begun.

The Water Resources Division: 1971 to 1976

In 1971, the Montana Water Resources Board became the Water Resources Division of the Montana Department of Natural Resources and Conservation. Originally, two Bureaus were created within the Water Resources Division: the Engineering Bureau and the Resources and Planning Bureau. Passage in 1973 of the Montana Water Use Act and of amendments to the Floodway Management and Regulation Act resulted in creation that year of the Water Rights Bureau and the Floodway Management Bureau. The Water Development Bureau was established in 1975 as a result of the passage of the Renewable Resource Development Act.

The Resources and Planning Bureau has had the primary responsibility for development of the state water planning program since 1971. In 1972, river basin planning began in the Columbia River Drainage with study of the Flathead River Basin (in cooperation with the Pacific Northwest River Basins Commission) and of the Clark Fork River Basin (in cooperation with the agencies of the U.S. Department of Agriculture). In 1975, river basin planning began in earnest in the Yellowstone River Basin. The major planning effort at this time is directed toward the study of individual river basins for the purpose of presenting specific alternatives and making needed recommendations in water and related land resource management for specific areas of the state.

In addition, numerous studies have been completed or are underway which will add to the water plan as it is formulated; a number of these are listed in Table 1. In view of the increasing number of studies, the need for coordination by the state of state-wide planning activities and for coordinated input into regional planning efforts (as called for in the Montana Water Resources Act of 1967) becomes apparent. In addition, it is important that much of Montana's water planning would not have been accomplished without the efforts of federal agencies and the availability of federal money.

The Western United States Water Plan was prepared under the direction of the Bureau of Reclamation as authorized by the Colorado River Basins Project Act of 1968. "Westwide," as this effort was commonly known, was to present the projected water needs of the entire area of the eleven western states to Congress for its consideration and use in studying future national water problems. This act also established a moratorium on diversions into or out of the Colorado River Basin, until 1978. Westwide experienced a reduction in funding in 1973; the resulting study findings were published in 1975 (U.S. Dept. of the Interior 1975).

In addition to these major regional planning efforts, many smaller area studies have been made which provide important data to the State Water Plan. State Water Plan data, in turn, will provide input into other federal and state resource planning, increasing the possibility that Montana's preferences are included in those efforts. Ongoing and recent federal water planning efforts in Montana are summarized in Table 1 on page 8, in which the following abbreviations are used:

FEDERAL AND REGIONAL PLANNING

Under the authority of the Federal Flood Control Act of 1944, regional planning by federal agencies, chiefly the U.S. Bureau of Reclamation and the U.S. Army Corps of Engineers, was initiated. The Missouri Basin Inter-Agency Committee was formed in 1945 and in 1969 released **The Missouri River Basin Comprehensive Framework Study,** which included the Missouri from its headwaters in Montana to the mouth of the river at St. Louis, Missouri. The Committee was dissolved in 1971 following creation of the Missouri River Basin Commission to carry on reconnaissance level studies in the basin. The **Columbia-North Pacific Region Comprehensive Framework Study** was prepared under the supervision of the Pacific Northwest River Basins Commission for all or parts of Washington, Oregon, Idaho, Wyoming, and western Montana. The commission is carrying out further reconnaissance level studies in the basin also. Other studies involving regional aspects of planning were made to support the Columbia River Water Treaty on the Kootenai River, ratified in 1964. The Columbia Interstate Compact Commission, active from 1950 to 1967 and consisting of representatives from several of the western states, made an attempt to promote the equitable division and apportionment of Columbia River Basin water but failed in its effort to ratify a compact between the states involved (Doerksen 1972).

FEDERAL AGENCIES

BOR — Bureau of Outdoor Recreation (USDI)
BR — Bureau of Reclamation (USDI)
EPA — Environmental Protection Agency
ERDA—Energy Research and Development Administration.
FS—Forest Service (USDA)
GS — Geological Survey (USDI)
SCS — Soil Conservation Service (USDA)
USDA — U S Department of Agriculture
USDI — U S Department of the Interior

STATE AGENCIES:

BMG — Montana Bureau of Mines and Geology
DFG — Montana Department of Fish and Game
DHES — Montana Department of Health and Environmental Sciences
DNRC — Montana Department of Natural Resources and Conservation
DSL — Montana Department of State Lands
MEAC — Montana Energy Advisory Council
MSU — Montana State University

REGIONAL AND LOCAL BODIES

APO — Area-wide Planning Organization
MRBC — Missouri River Basin Commission
OWRC — Old West Regional Commission
PNRBC — Pacific Northwest River Basins Commission

TABLE 1
WATER PLANNING STUDIES IN MONTANA: ONGOING OR COMPLETED SINCE 1971

Study	Area of Study	Lead Agency*	Time of Completion	Study Objectives/ Subject of Study
		COLUMBIA RIVER BASIN		
FEDERAL:				
Flathead Wild and Scenic River Study	North Fork from the Canadian Border to its confluence with the Middle Fork; Middle Fork from its headwaters to its confluence with the South Fork; South Fork from its origin to Hungry Horse Reservoir.	FS	7/73	Define recreation potential for each river section and recommend congressional action.
Clark Fork of Columbia Type IV Study**	Western Montana	USDA, DNRC	FY 77	Identify water and related land resource problems and investigate their solution using existing USDA or state programs
Bitter Root RC&D Project	Ravalli, Missoula, Mineral Counties	SCS, Bitter Root RC&D Council	Ongoing	Develop economic development plan for conservation and use of area resources.
STATE:				
Flathead Level B Study**	Flathead River Basin	DNRC, PNRBC	Early 76	Develop alternatives for land and water resource use.
North Fork Flathead Cabin Creek Development Study	North Fork Flathead Basin	DNRC	1/77	Study effects of Cabin Creek coal development in Canada on North Fork of Flathead.
Flathead Drainage 208 Project	Flathead and Lake Counties	Flathead Drainage 208 Project Board	FY 77	Identify water quality problems and recommend solutions
		MISSOURI RIVER BASIN		
FEDERAL:				
Missouri Wild and Scenic River Study	Missouri mainstem from Ft. Benton to Rocky Point	BOR	1/75	Study value of Missouri River for preservation in free flowing state
Headwaters RC&D Project**	Beaverhead, Deer Lodge, Granite, Jefferson, Madison, Powell, & Silver Bow Counties	SCS, Headwaters RC&D Council	Ongoing	Develop economic development plan for conservation and use of area's resources
STATE:				
Milk River Water Management Study	Milk River Drainage	DNRC, BR	FY 76	Investigate water augmentation proposals

Table 1 continued

Study	Area of Study	Lead Agency*	Time of Completion	Study Objectives/ Subject of Study
YELLOWSTONE RIVER BASIN				
FEDERAL:				
Montana-Wyoming Aqueducts Study**	Southeastern MT, Northeastern WY	BR	4/72	Investigate water resource availability for coal development
Yellowstone Wild & Scenic River Study**	Yellowstone mainstem from Gardiner to Pompey's Pillar	BOR	2/75	Study impact of proposed Billings Water Supply unit on Yellowstone River
Wind, Bighorn, Clarks Fork Type IV Study**	Stillwater, Clarks Fork, and Bighorn River Basins	USDA, DNRC	12/74	Identify water and related land resource problems and investigate their solution using existing USDA or state programs.
Yellowstone Level B Study	Yellowstone River Basin	MRBC, DNRC	10/77	Recommend near-term resource management plan compatible with long-term goals of nation, region, and state.
Powder River Basin Energy Study	Powder River Basin	ERDA	FY 80	Identify alternative futures; economic and environmental evaluations
Beartooth RC&D Project	Carbon and Stillwater Counties	SCS, Beartooth RC&D Council	Ongoing	Develop economic development plan for conservation and use of area's resources.
STATE:				
Powder River Project Development Study	Powder River Basin	DNRC	Early 77	Evaluate water resource development and storage potential on the Powder River
Tongue River Project Development Study	Tongue River Basin	DNRC	Late 76	Evaluate water resource development and storage potential on the Tongue River
Yellowstone River State Water Plan Study	Yellowstone River Basin	DNRC	FY 77	Identify alternative futures; economic and environmental evaluations
Old West Regional Commission Impacts on the Yellowstone River Study	Yellowstone River 8asin	DNRC (funded by OWRC)	FY 77	Investigate possible impacts of large water withdrawals.
Blue Ribbons of the Big Sky 208 Study	Gallatin County, Madison River	DHES, APO	FY 77	Identify water quality problems and recommend solutions
Middle Yellowstone 208 Study	5 counties along the Middle Yellowstone	DHES, APO	FY 77	Identify water quality problems and recommend solutions
Lower Yellowstone-Tongue 208 Study	6 counties along the Lower Yellowstone & Tongue	DHES, APO	FY 77	Identify water quality problems and recommend solutions

Table 1 continued

Study	Area of Study	Lead Agency*	Time of Completion	Study Objectives/ Subject of Study
		STATE-WIDE, REGIONAL, AND INTERNATIONAL		
INTERNATIONAL:				
Poplar River Water Allocation Study	Poplar River Basin in Canada and USA	Poplar River Task Force, DHES, DNRC, etc.	FY 76	Divide water resources between U.S. and Canada
Missouri River Basin Commission Comprehensive Coordinated Joint Plan	The entire Missouri River Basin in 10 states and Canada	MRBC, DNRC	FY 77	Develop alternatives for water and land resource use in the basin.
FEDERAL:				
North Central Power Study**	North Central & Rocky Mountain areas	USDI	10/71	Investigate feasibility of energy production by mine mouth, coal-fired plants and associated UHV transmission.
Westwide Study**	11 states	BR	4/75	Evaluate the critical water problems of the western states.
Northern Great Plains Resource Program**	Northern Great Plains	USDI and others	8/75	Investigate effects of coal development on the Northern Great Plains.
Section 303e Water Quality Management Plans**	All river basins in Montana	EPA, DHES	FY 76	Establish priorities and action schedules for resource expenditures; implementation study.
Eastern Montana Basins Study**	26 Eastern Montana counties	BR	FY 76	Identify and evaluate resources for future development.
Western Energy Expansion Study	17 western states	BR	10/76	Survey and identify ways to generate additional electrical power, including hydropower and alternative sources.
Army Corps of Engineers Umbrella Study	Missouri River mainstem from Sioux City, IA, to Three Forks, MT	Corps of Engineers	FY 77	Formulate solutions to existing problems with reservoir system; determine need for system modification to meet water needs
Pacific Northwest River Basins Commission Comprehensive Coordinated Joint Plan	Columbia Basin and Pacific slope drainages in Washington, Oregon, Idaho, Montana, and Wyoming	PNRBC, DNRC	FY 77	Develop alternatives for water and land resource use in the Pacific Northwest.
Five-State Madison Ground-Water Study	The eastern third of Montana plus parts of Wyoming, Nebraska, and North and South Dakota	GS	1981	Investigate the hydrology of the Madison Limestone Formation and its ability to supply large quantities of water
STATE:				
Water Quality Management Plan	State-wide	DHES, DNRC, DFG	7/76	Evaluate waste-water discharge and sediment
General Energy Policy and Recommendation Study	State-wide	MEAC	Early 77	Develop an energy policy for Montana
Saline-Alkali Control Program	Eastern two-thirds of state	DSL, USDA, MSU, BMG	6/77	Examine saline seep situation.
Montana Ground Water Study	Emphasis on Fort Union Coal Area	BMG, GS	6/77	Investigate the hydrology of the Fort Union Formation and strip mining's effects on it

*See page 7 for explanation of abbreviations

**These Studies have resulted in publications which are included in the "Selected Bibliography."

METHODOLOGY OF THE STATE WATER PLAN

PLANNING PROCEDURE

Inventory Series Report Number 4, **Water Resources and Planning**, published in 1968, presented the basic scope and outlined the assumptions and study procedure to be tentatively followed in conducting a state water planning program. However, many changes have occurred since then which necessitate the redefinition of the objectives, procedures, and guidelines to be included in the general planning methodology. In 1968, the terms "environment," "ecology," "multiobjective planning," and "quality of life" were seldom mentioned in everyday planning activities. The emphasis was on economic development, conservation, and utilization of our resources, with planning centered around the ultimate use of the water resource. Today, most of the objectives, procedures, and guidelines which were set up for water and related land resource planning in 1967 and 1968 still pertain, but there are new ideas, new considerations, new people conducting planning programs, and more people demanding the information being produced in comprehensive studies such as those Montana is conducting. Because of this change in planning approach and because of the current emphasis on public involvement in the planning process, a redefinition of the State Water Plan methodology is in order.

The four phases of the State Water Plan outlined by the Montana Water Resources Board in 1968 are given below, modified to reflect changes in the planning approach.

Phase One: The Inventory

The first phase of the State Water Plan is the resource inventory, which is the accumulation of detailed knowledge of the water and related land resources of the state of Montana and their present management and use. The inventory phase of the water plan has resulted in the publication of a number of inventory series reports containing the mass of information acquired during the study. The following have been printed:

No. 1. *Directory of State of Montana, Federal Agencies and Private Groups Active in the General Field of Water Resources* (1968 and 1971).

No. 2. *Water Resources Programs Conducted by Government Agencies in Montana* (1969).

No. 3. *Montana Register of Dams,* a compilation of information on storage reservoirs having a capacity of 50 acre-feet or more (1968).

No. 4. *Water Resources and Planning,* an explanation of the State Water Plan, its authorization, scope, and objectives (1968).

No. 5. *Montana's Water Laws: A Resume'* (1968).

No. 6. *Catalogue of Stream Gaging Stations in Montana,* a collection of historical stream discharge records to 1970 (1968 and 1972).

No. 9. *Summary of Potential Projects in Montana,* a compilation of information on possible future developments of water storage and control projects (1969).

No. 10. *Bibliography of Montana Water Resources and Related Publications* (1969).

No. 11. *An Atlas of Water Resources by Hydrologic Basin,* a 15-map atlas of Montana's drainage basins and resources (1970).

No. 12. *Montana's State Water Plan, A Progress Report,* a report to Montana's 42nd Legislature (1970).

No. 13. *Water Use in Montana* (1975).

No. 16. *A Groundwater Report of Montana* (1969).

Information is currently being gathered for publication of several additional inventory series reports. These include:

No. 7. *Economic Aspects of Water Use.*

No. 8. *Patterns of Management and Administration,* a review of past trends in water and related land use which affect Montana's resources and their development.

No. 14. *An Inventory of Related Land Resources.*

No. 15. *A History of Water Development in Montana.*

Also involved in this phase is the computerization of much of the published (and unpublished) data, allowing easy and rapid use of the water and related land resource information for subsequent phases of water planning.

The inventory reports will continue to be published and updated as new and better information is gathered, as the need for specific information arises, and as the expertise becomes available to do necessary studies.

Phase Two: Requirements and Projections
The second phase of the plan involves the development of water requirements and projections for future water and related resource use from a study of the information regarding present water use obtained in phase one. (These general water requirements and projections are presented on a state-wide basis in **The Framework Report, Volume Two.)**

More detailed regional requirements and projections will be established for use in subsequent river basin planning. To aid in development of these requirements, detailed economic projections are being prepared by the state of Montana for use in planning for Montana's growth while reflecting Montana's outlook for the future.

Phase Three: Plan Formulation
Phase three involves the development and publication of alternative plans, programs, and projects to be implemented in each of three time periods: between the present and 1980, between 1980 and 2000, and between 2000 and 2020. Development selected will be determined by the findings of the inventory and water-needs phases of the water plan, as well as from the findings of other region-, state-, basin-, and county-wide planning efforts. Public and agency comment will be used in determining the final water plan recommended for adoption.

Phase Four: Implementation
The fourth phase of the State Water Plan is the implementation of recommended plans, programs, and projects. Some of this implementation will take place concurrently with present planning efforts; much will be the result of future detailed surveys of problem areas.

OBJECTIVES

Until the mid-1960's, water resource planning was largely based on the evaluation of specific projects as related to one or more uses which had an economic value attached to them. Irrigation was the primary benefit of small watershed projects. Power and flood control provided the impetus for building larger projects; recreation grew to be a recognizable benefit associated with nearly all reservoirs.

With the advent of nationwide water resource planning, more consideration was given to the evaluation of all benefits upon which a value could easily be placed. A limitation still existed, however, because specific federal and state laws restricted the scope of project benefits which could be studied. Likewise, a study of the detrimental effects of potential water development projects was not adequately required, and, while the environmental effects were often adverse, they were seldom anticipated.

Today, with multiobjective planning, it is possible not only to evaluate the monetary and nonmonetary effects of development, but to better evaluate the advantages of nondevelopment as well.

The overall objective of the State Water Plan is still *to set out a progressive program for the conservation, development, and utilization of Montana's water resources for the maximum economic and social prosperity of the people.* However, under the multiobjective planning theory, all programs will be evaluated from the standpoints of economic efficiency, environmental quality, and regional development.

This planning procedure, designed by the U.S. Water Resources Council, was presented to the states and federal agencies for approval as a part of the "Proposed Principles and Standards for Planning Water and Related Land Resources." They were modified and adopted as published in the *Federal Register* of September 10, 1973. These principles provide the basis for federal participation with river basin commissions, states, and others in the preparation, formulation, and evaluation of plans for states, regions, and river basins, and for federally assisted water and land resource programs and projects throughout the United States. Therefore, the use of multiobjective planning in the Montana water planning program provides not only a logical and objective method of developing a program for the maximum economic and social prosperity of her citizens, but it fits into and is required by the federal water planning principles and standards. A broader discussion of the technique is included below under "Statement on the Final Plan" (page 14).

ASSUMPTIONS

In formulating a varied and broad program such as the State Water Plan, it is necessary first to establish some assumptions which are largely based on national or international conditions over which the state has little or no control but which could have appreciable effect upon decisions and recommendations arrived at by the plan. These assumptions are not predictions of what will happen in the future, nor has any judgment been made as to the desirability of these conditions. The statements simply reflect trends which are likely to continue and which are likely to influence water use decisions, thereby providing state water planners with a frame of reference within which to structure their efforts. It is possible that some of the assumptions will prove to be inaccurate; however, it can be said in their defense (1) that they agree generally with those made by regional planners and by planners in other states, and (2) that, as stated below, comprehensive planning under the State Water Plan is concentrated on the next 10 to 15 years, and these assumptions should be reasonably accurate for at least that period of time.

Eleven tentative assumptions were originally developed for consideration by the planning staff in 1968; these have been modified, reduced in number, and rewritten to reflect changing national and international conditions as follows:

1. There will be no major wars or depressions which will have extreme effects on long-run economic growth.

2. Certain governmental and private organizations will follow policies designed to stimulate economic growth in the state.

3. Water development in Montana will be for multiple purposes whenever possible.

4. The utilization of water and the treatment of return flows will conform to the water quality standards set by the Montana Department of Health and Environmental Sciences and the Environmental Protection Agency.

5. Unemployment of the civilian labor force will tend to be higher at the state level than at the national level.

6. Montana's agricultural products will supply at least the same share of national requirements in the future that they have in the past.

7. Irrigation efficiency is a function of economics and as such is likely to increase.

8. Efforts will be made to meet power needs of the future.

9. Agricultural, commercial, and industrial productivity will increase, partially as a result of greater efficiencies achieved through evolving technologies.

Certain other considerations have also been recognized. Among these are the following:

1. Planning can best be accomplished by concentrating on comprehensive planning for the near future, i.e., the next 10 to 15 years, and projecting needs for the years 2000 and 2020.

2. In a state where flood flows make up more than 50 per cent of total stream run-off (Montana Water Resources Board 1968), streamflow augmentation through development of surface water storage projects will be a primary consideration to provide for the use of the greatest quantity of water for all purposes.

3. Because the second greatest supply of usable water is in alluvial (ground-water) basins closely associated with principal surface water sources, ground water will be studied in conjunction with surface water in order to modulate and augment flows, especially during drought periods.

GUIDELINES

The Water Resources Division, in order to formulate a State Water Plan, has set guidelines to determine the nature of the investigations to be accomplished. These guidelines will, to a large extent, influence the outcome of the study. They reflect important public policy and, by directing planners, eliminate wasting time in unacceptable planning efforts. For these reasons, it is important that the guidelines be understood and accepted by everyone involved with the study.

1. The State Water Plan will serve the general welfare of the people by striving toward a balance of economic efficiency (considering such factors as marketing potential and national production allocations), resource development (at regional levels as well as individual project levels), and environmental quality (the environmental effects of development will be weighed against the benefits of nondevelopment).

2. The plan will describe alternatives formulated to meet the needs of the people for goods, services, and benefits derived from water and related land resources and make recommendations for management of those resources. Available significant information on each alternative will be presented by subbasin and, where applicable, by county.

3. The importance of public needs and desires and the prerequisite of overall public involvement throughout the entire planning process will be fully recognized; public response to each management alternative will be evaluated.

4. The plan will give priority to (a) in-basin use of water resources (that is, water needs within the basin will be met to a reasonable degree before water transfers

to other basins are considered, even though inter-basin transfer of water now exists in Montana and will continue to offer a reasonable means of water and related land development), and (b) Montanans' interests in water use (even though federal and regional interests will also be recognized).

5. The plan will consider the flexibility of state and federal laws, policies, and institutional relationships governing both short- and long-range water planning and development, and changes will be recommended in those laws, policies, and relationships if necessary to allow the development of selected alternatives.

6. The plan will be formulated utilizing only those waters rightly available for Montana's uses. Full consideration will be given to all interstate agreements and existing water rights within Montana.

7. Other planning efforts will be evaluated to determine the full impact of other alternatives for uses of Montana's water and related land resources.

8. Due to anticipated rapid changes in social, economic, environmental, technological, and physical factors, both this framework study and the basin planning efforts will be formulated so as to provide a flexible guide for water and related land resource planning in Montana now and well into the future. The general schemes of water use will be capable of serving needs which may vary widely in magnitude from those anticipated or being considered at the present time; in addition, those portions of the plan which are not implemented or which otherwise become out-of-date will be reviewed and revised to meet the water planning objectives.

STATEMENT ON THE FINAL PLAN

RIVER BASIN STUDIES

Early in the planning process it was decided to divide the state into river basin planning units to facilitate study of the resources and their relationships. These units fall into three categories according to size. The major basins in the state are the drainages of the Clark Fork of the Columbia, the Missouri, and the Yellowstone Rivers, which are further divided into submajor and minor drainage basins as shown on the map on the opposite page. These submajor and minor drainage basins have provided the basis for the major portion of data gathering for the State Water Plan.

Concurrently with the completion of **The Framework Report**, reconnaissance-level evaluations of the water and related land resources of these basins will be made. Each of the three major basins will be considered a planning area. This approach, which can be called the watershed planning approach, must be flexible and allow for the study of larger or smaller problem areas as the need arises.

The smaller river basin studies will be prepared in an attempt to resolve the short-range problems identified by the framework study and to identify foreseeable long-range problems, develop solutions to them, and make recommendations for solving these problems. Studies are presently nearing completion for the Flathead River Basin in western Montana and for the Yellowstone River Basin in eastern Montana.

PRESENTATION OF DATA

One of the major problems encountered in water resources planning has been the failure of planning agencies to present data to the public in a usable form. In planning for water utilization, for example, the logical method is the delineation of river basins and the gathering of data accordingly. Unfortunately, that method ignores the political subdivisions used for nearly every other type of data manipulation.

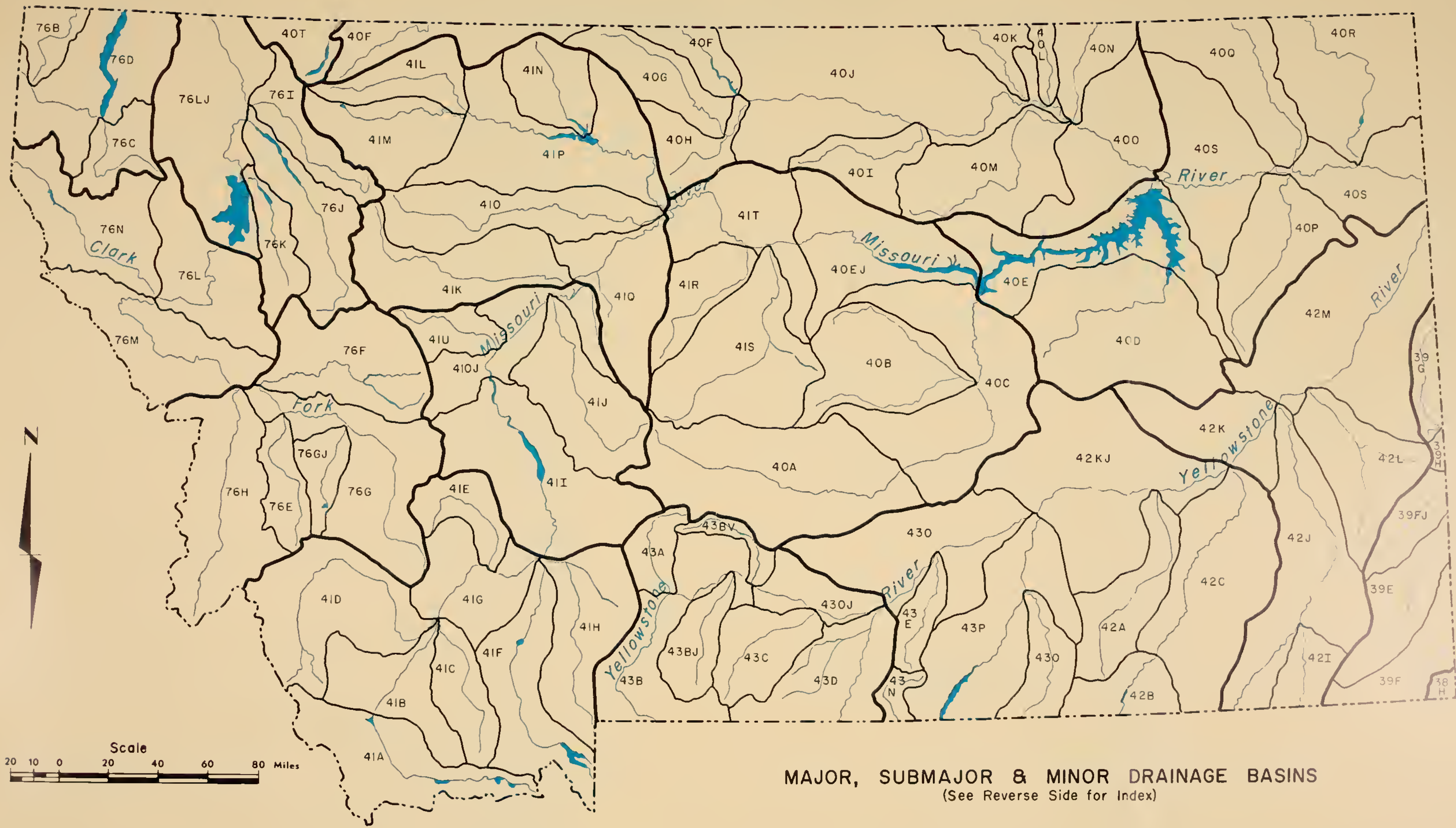
The State Water Plan will attempt to overcome this problem by presenting as much data as possible on both the county and the river-basin levels. It is hoped that the presentation of information in this manner will aid city and county officials. Planning figures will not require as much time to group for a county such as Carter, which contains two submajor and seven minor basins, or to separate for a county such as Wheatland, which lies entirely within one minor basin. This method of data presentation will also stress the importance of river basin planning as related to county-wide planning, and vice versa; also, the people responsible for the implementation of alternative recommendations, other decision makers, and interested groups will all share a common information base.

THE PLANNING PROCESS FOR EACH BASIN

The following planning steps (which have been related to the four phases of the State Water Plan as outlined on pages 11 and 12) will be performed for each basin:

DRAINAGE BASINS

dex)



MAJOR, SUBMAJOR & MINOR DRAINAGE BASINS
(See Reverse Side for Index)

1. **Gather all pertinent data relevant to the study area (phase one: inventory).**
This will include compilation of data from all reliable sources, and, where informational gaps exist, appropriate methods and techniques will be used for estimation. Once the information has been compiled, it will be correlated with information gathered for other basins.

2. **Specify the components that are relevant to the planning area (phase two: requirements and projections).**
From the outset, the Water Resources Division will consult federal, regional, state, and local groups to identify the particular needs and problems that are significantly related to the use and management of the resources in each planning area. The types of goods, services, developments, and environmental conditions desired will be defined so that meaningful alternative levels of growth can be identified.

3. **Formulate alternative plans to reach differing levels of development for both the study area and the entire state (phase three: plan formulation).**
Based upon identified needs and problems, alternative plans will be prepared and evaluated with respect to their contribution to the objectives of the State Water Plan. The effects of the alternative plans will be considered on both the basin- and state-wide levels.

4. **Review the objectives and analyze the differences between the alternatives (phase three: plan formulation).**
A summary of anticipated beneficial and adverse effects for each alternative will be prepared in graphic form so that the differences can be clearly shown and analyzed. This analysis will enable the planning team and others to compare all anticipated effects of all alternatives.

5. **Select a plan based upon an evaluation of the trade-offs among the various alternatives (phase three: plan formulation).**
From the analysis of alternatives, the Water Resources Division will select a plan. Other plans representing differing priorities among the objectives will also be included in the report, as will detailed analyses of the trade-offs involved and the basis for choosing the selected alternative.

6. **Distribute the report for review (phase three: plan formulation).**
As each river or subbasin study is completed (according to a priority system based upon the demand for the resource and the need for management), it will be published and distributed to government agencies and to the public. The needed public education and input will be obtained through a comment period and a public hearing held within the area encompassed by the selected and alternative plans.

7. **Present a recommended plan for adoption (phase four: implementation).**
Following the review (and possible subsequent modification of the report), the Department of Natural Resources and Conservation will recommend a final basin plan to the Board of Natural Resources and Conservation. Adoption of a plan by the Board can be considered the initial implementation step, although complete implementation can result only from active participation over an extended period of time by all parties concerned, including both public officials and private citizens, and probably will require enactment of additional legislation.

THE STATE WATER PLAN

Taken together, the publications will make up the State Water Plan. Publication of a report summarizing the basin studies is also anticipated. It is likely that frequent updating of State Water Plan publications and the publication of progress reports will be necessary to keep all involved in the decision-making process aware of changes in Montana's water resources situation.

MILK
40F Milk River above Fresno Reservoir
40G Sage Creek
40H Big Sandy Creek
40I Peoples Creek
40J Milk River between Fresno Reservoir and Whitewater Creek
40K Whitewater Creek
40L Frenchman Creek
40M Beaver Creek
40N Rock Creek
40O Milk River below Whitewater Creek including Porcupine Creek

MISSOURI-FORT PECK
40D Dry Creek
40E Missouri River between Musselshell River and Fort Peck Dam
40P Redwater River
40Q Poplar River
40R Big Muddy Creek
40S Missouri River below Fort Peck Dam
40T St. Mary River

YELLOWSTONE RIVER BASIN (AND LITTLE MISSOURI DRAINAGE)

UPPER YELLOWSTONE
43A Shields River
43B Yellowstone River above and including Bridger Creek
43BJ Boulder River
43BV Sweet Grass Creek
43C Stillwater River
43D Clarks Fork Yellowstone River
43QJ Yellowstone River from Bridger Creek to the Clarks Fork Yellowstone

MIDDLE YELLOWSTONE
43E Pryor Creek
43N Shoshone River
43O Little Bighorn River
43P Bighorn River below Greybull River
43Q Yellowstone River between Clarks Fork Yellowstone and Bighorn River
42A Rosebud Creek
42B Tongue River above and including Hanging Woman Creek
42C Tongue River below Hanging Woman Creek
42KJ Yellowstone River between Bighorn River and Tongue River

LOWER YELLOWSTONE
41I Little Powder River
42J Powder River below Clear Creek
42K Yellowstone River between Tongue and Powder Rivers
42L O'Fallon Creek
42M Yellowstone River below Powder River

LITTLE MISSOURI
39E Boxelder Creek
39F Little Missouri River above Little Beaver Creek
39FJ Little Beaver Creek
39G Beaver Creek
39H Little Missouri below Little Beaver Creek

38H Belle Fourche River above Cheyenne River

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   This will include compilation of data from all reliable sources, and, where informational gaps exist, appropriate methods and techniques will be used for estimation. Once the information has been compiled, it will be correlated with information gathered for other basins.

2. **Specify the components that are relevant to the planning area (phase two: requirements and projections).**
   From the outset, the Water Resources Division will consult federal, regional, state, and local groups to identify the particular needs and problems that are significantly related to the use and management of the resources in each planning area. The types of goods, services, developments, and environmental conditions desired will be defined so that meaningful alternative levels of growth can be identified.

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PART TWO

WATER AND RELATED LAND RESOURCES OF MONTANA

PHYSICAL FEATURES

Montana may be divided into four topographic regions: the glaciated plains of northeastern Montana, the sedimentary plains of southeastern Montana, the foothills of central Montana, and the mountainous regions of western and south-central Montana (see map on page 22). These divisions are not sharply defined, however, because the foothills region interrupts the plains throughout the central portion of the state, and intermittent mountain ranges extend well into both foothills and plains.

The topography of the glaciated plains, which lie generally north of the Missouri River and east of the Rocky Mountains, is subdued due to the erosive action of ancient glaciers that rounded the hills and filled in the valleys. The sedimentary plains, with more relief, extend east of the Continental Divide from the Missouri River south to the Wyoming border. These two areas, commonly known as the Great Plains of Montana, are characterized by flat, treeless expanses and large, gently rolling hills.

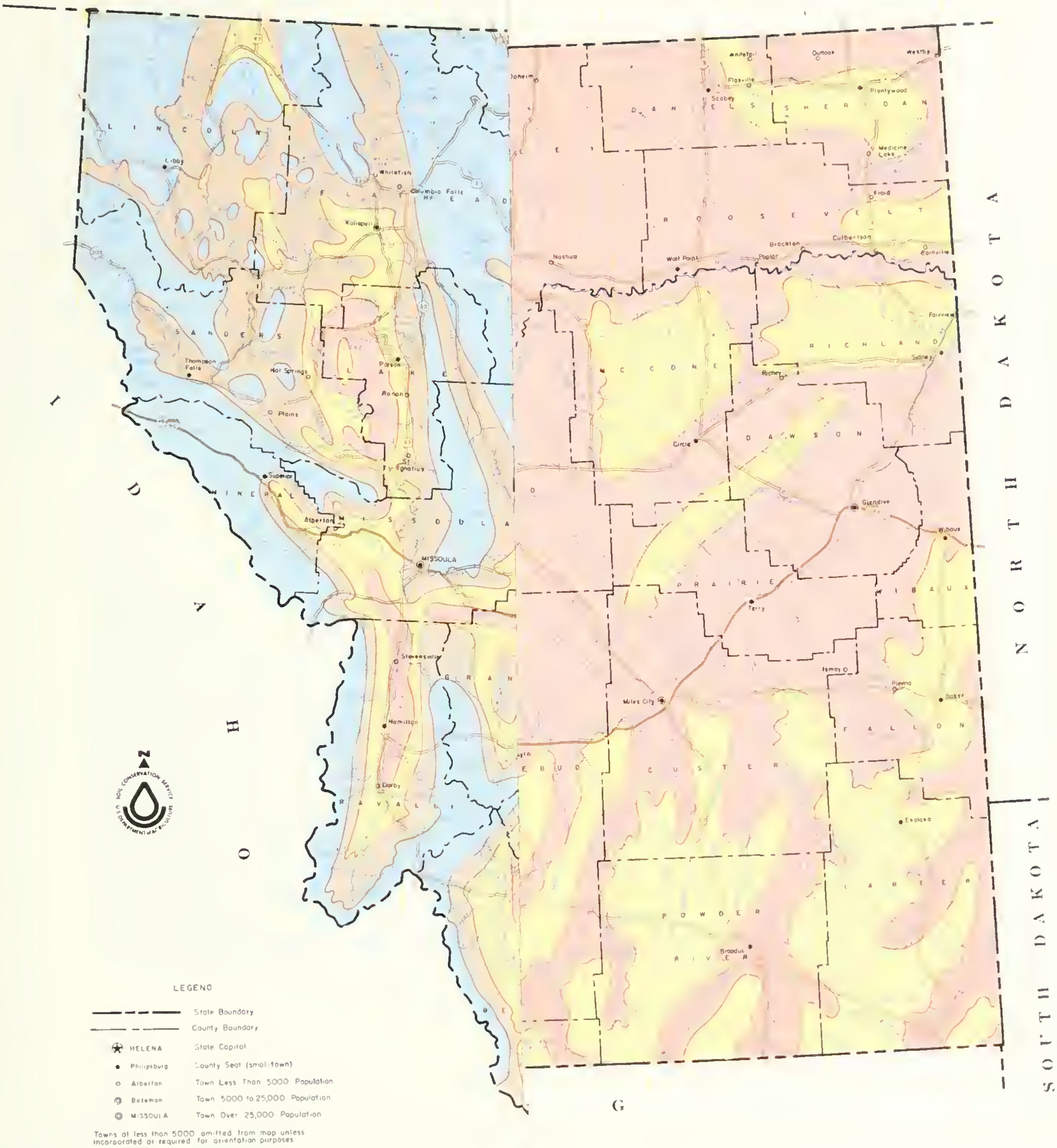
THE MISSOURI RIVER

TABLE 2

RECORDS OF AVERAGE PRECIPITATION FOR SELECTED STATIONS (in inches)

STATION*	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual	Y.O.R.**
Billings AP	.54	.60	1.05	1.31	1.88	2.55	.90	.90	1.19	1.09	.63	.59	13.23	38
Butte AP	.42	.44	.65	.90	1.74	2.41	1.20	1.03	1.08	.67	.49	.48	11.48	78
Culbertson	.34	.29	.42	.94	1.60	3.36	1.79	1.49	1.08	.76	.45	.32	12.84	65
Glasgow AP	.48	.41	.56	1.01	1.49	2.98	1.33	1.49	.96	.66	.47	.45	12.27	17
Glendive	.39	.39	.62	1.03	1.60	3.17	1.83	1.48	.90	.71	.41	.30	12.73	80
Great Falls AP	.61	.74	.92	.98	2.10	2.90	1.28	1.26	1.20	.73	.75	.60	14.07	81
Hamilton	.86	.88	.67	.74	1.61	1.85	.79	.64	1.04	1.02	1.08	1.04	12.22	62
Helena AP	.47	.43	.70	.83	1.56	2.23	1.03	.89	.95	.66	.57	.53	10.85	93
Kalispell AP	1.37	1.00	.96	1.04	1.67	2.21	1.04	1.09	1.04	1.24	1.43	1.33	15.42	23
Lewistown AP	.57	.61	.85	1.00	2.60	3.87	1.58	1.53	1.44	1.07	.71	.69	16.52	77
Miles City AP	.44	.37	.65	1.06	1.73	2.71	1.34	1.24	.96	.87	.43	.37	12.17	35
Missoula AP	.92	.87	.73	.97	1.87	1.91	.85	.72	1.02	.99	.90	1.08	12.83	37
Norris Madison PH	.76	.76	1.34	2.01	2.55	3.14	1.38	1.13	1.66	1.38	.87	.73	17.71	66
Red Lodge	.82	.79	1.71	2.85	3.07	3.21	1.39	1.16	1.71	1.42	1.20	.69	20.02	75

*AP — Airport, PH — Powerhouse
**Years of Record
SOURCE: U.S. Department of Commerce 1972



AVERAGE ANNUAL PRECIPITATION ZONES*

MONTANA

NOVEMBER 1970

10 0 10 20 30 40 MILES

SCALE 501,000

USGS National Atlas 1:1,000,000 Albers Equal-Area projection (1967) used as source for base map and adapted for SCS use

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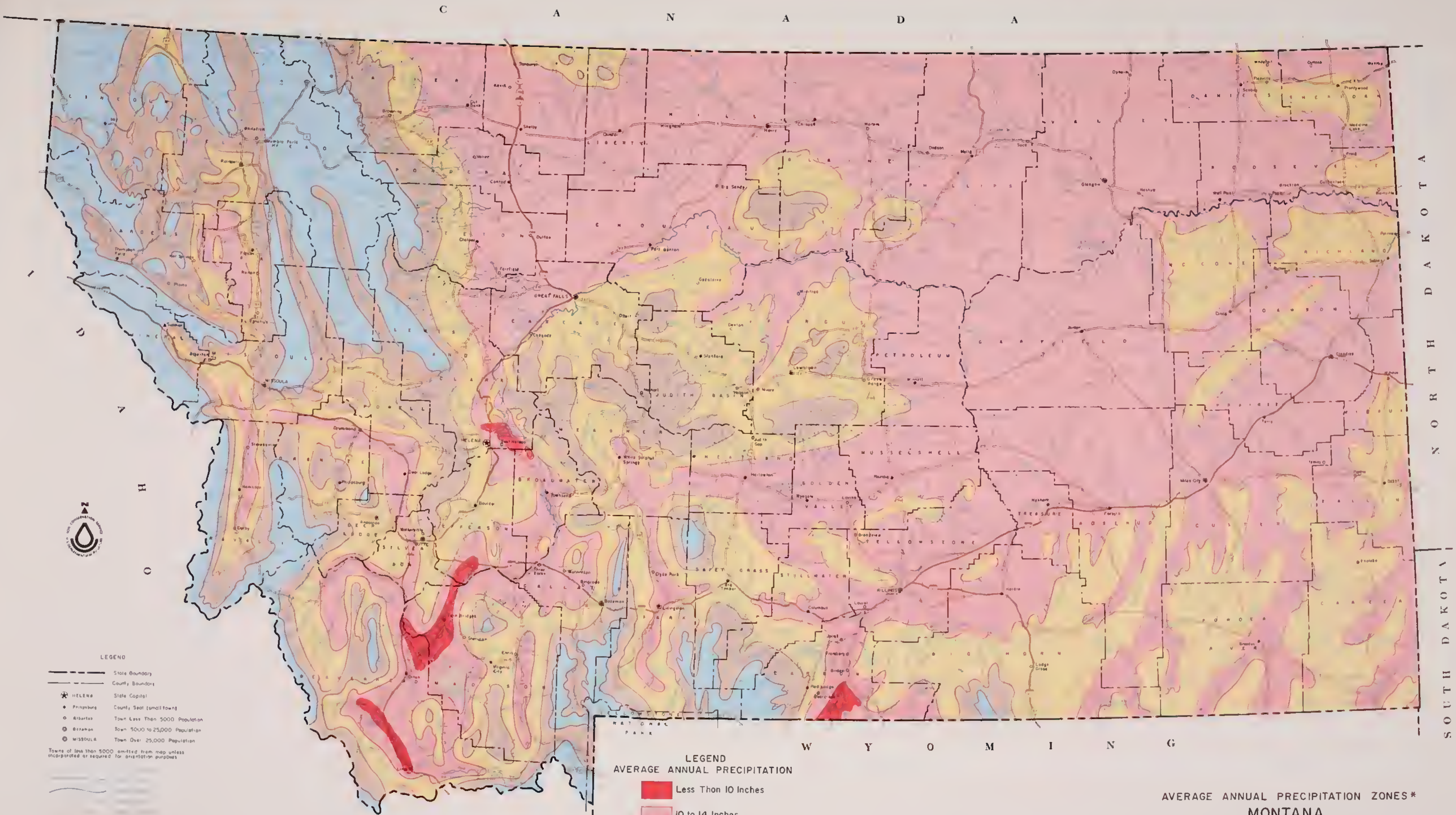
U.S. DEPARTMENT OF AGRICULTURE

MONTANA

SOIL CONSERVATION SERVICE



LEGEND
AVERAGE ANNUAL PRECIPITATION

- Less Than 10 Inches
- 10 to 14 Inches
- 14 to 20 Inches
- 20 to 30 Inches
- More Than 30 Inches

* Based on 1953-67 period and obtained from SCS Snow Survey, Soil Survey and Weather Bureau data

USGS National Atlas 1:1,000,000 Albers Equal-Area projection (1967) used as source for base map and adapted for SCS use

AVERAGE ANNUAL PRECIPITATION ZONES*
MONTANA

NOVEMBER 1970

10 0 10 20 30 40 MILES

SCALE 1:2,500,000

M7-S-21861-N

TEMPERATURE

Montana's large area, great differences in elevation, and location on the North American Continent result in a widely varying pattern of temperatures. The highest temperature recorded in the state was 117° F at Glendive on July 20, 1893, and at Medicine Lake on July 5, 1937. The coldest temperature ever recorded in the continental United States was -70° at Rogers Pass, 40 miles northwest of Helena, on January 20, 1954. Maximum temperatures exceeding 100° have occurred at most of the recording stations in the state, and temperatures ranging well below zero occur almost every winter. The greatest temperature extremes occur east of the divide, and wide daily ranges in temperature occur state-wide during hot periods in the summer. July is the warmest month of the year, and January is the coldest. Table 3 (page 30) shows average temperature records for selected stations in Montana.

Although Montana winters are cold, the growing or freeze-free season lasts three months or more in most of the agricultural areas (see Freeze-Free Season Map on page 31). Much of Montana has an average freeze-free period of longer than 110 days, allowing for the growth of a wide variety of crops. Miles City has the longest freeze-free season in the state, 135 days in length. The longer growing seasons invariably are found in the lower, warmer, less rugged valleys of the state. On the other hand, there is no dependable freeze-free season in many of the high mountain valleys in the western section of the state; freezing temperatures may occur during any month of the year. Several varieties of hardy grasses thrive in such localities, however, and produce a large amount of feed for stock grazing.

EASTERN MONTANA PRAIRIE

EVAPORATION

Substantial amounts of water are lost through evapotranspiration — a combination of evaporation from water surfaces and the soil and transpiration from plants. The Average Annual Potential Evapotranspiration Map on page 33 shows the potential for loss of water through evapotranspiration.

The rate of evaporation from lakes, rivers, storage reservoirs, and canals is largely dependent on wind speed, temperature, sun angle, and relative humidity. The average annual total loss in inches by evaporation from shallow lake surfaces ranges from 35 to 50 inches across the state, as shown in the Mean Annual Evaporation: Shallow Lakes and Reservoirs Map on page 35 (U.S. Dept. of Agriculture 1974a).

Many reservoirs and stock ponds in Montana are comparatively shallow with respect to their volume, and the resulting large surface area combined with the high evaporation rates common to the state significantly reduce available water supply. Steps have been taken in some areas of the nation to reduce evaporation from such water bodies, but little has yet been done in Montana.

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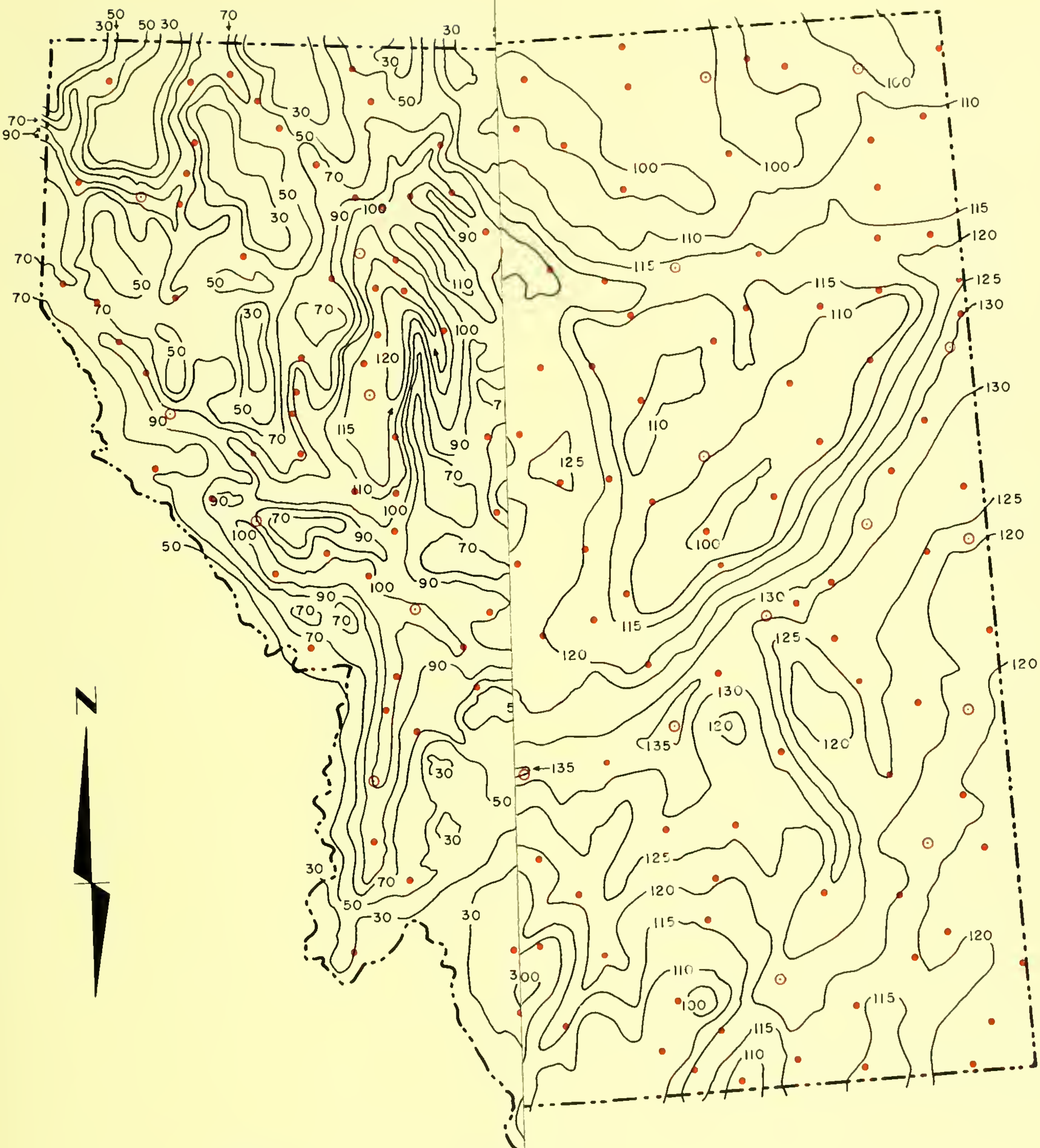
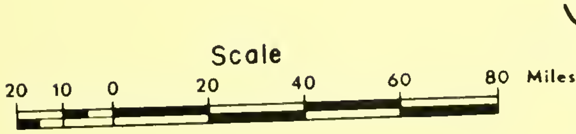
TABLE 3

RECORDS OF AVERAGE TEMPERATURE FOR SELECTED STATIONS

STATION*	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual	Y.O.R.**
Billings AP	23.2	25.7	33.7	46.0	56.8	65.1	74.7	71.9	60.4	49.5	35.1	29.2	47.5	38
Butte AP	15.1	19.5	26.3	38.5	47.3	54.3	62.5	60.3	51.2	42.6	27.7	20.1	38.7	73
Culbertson	9.5	13.4	25.5	42.6	55.9	62.6	70.5	68.2	57.2	45.3	27.9	17.5	41.3	53
Glasgow AP	9.8	13.6	26.7	43.4	55.1	62.3	70.7	67.8	56.7	45.4	28.2	17.7	41.5	17
Glendive	15.2	18.7	30.5	46.5	58.4	66.3	74.7	72.0	60.8	48.8	32.5	22.6	45.6	72
Great Falls AP	22.1	23.8	30.7	43.6	53,0	59.9	69.4	66.8	57.4	47.5	34.3	27.3	44,7	80
Hamilton	24.8	29.3	36.9	46.7	54.6	60.3	68.2	67.1	57.7	47.4	34.5	28.5	46.3	57
Helena AP	18.6	23.2	31.4	43.3	52.9	59.5	68.4	66.2	56.0	45.6	31.6	24.2	43.4	93
Kalispell AP	19.8	24.5	31.8	43.7	52.2	58.6	65.7	63.1	54.7	43.9	31.0	25.0	42.8	23
Lewistown AP	20.2	22.5	28.7	41.2	51.0	57.5	66.3	64.2	54.9	45.9	32.6	26.1	42.6	64
Miles City AP	16.5	30.3	30.9	45.7	57.4	65.6	75.3	72.6	61.0	49.0	32.6	23.2	45.8	35
Missoula AP	19.2	25.0	33.7	44.3	52.6	59.5	67.0	64.8	55.4	44.0	30.5	23.5	43.2	37
Norris Madison PH	25.5	28.4	34.5	45.2	54.4	61.4	70.8	69.2	59.9	49.7	36.5	30.3	47.2	65
Red Lodge	23.7	23.4	28.4	39.3	48.9	55.8	64.7	62.5	53.7	44.7	32.0	26.7	41.8	69

*AP — Airport, PH — Powerhouse
**Years of Record
SOURCE U S Department of Commerce 1972





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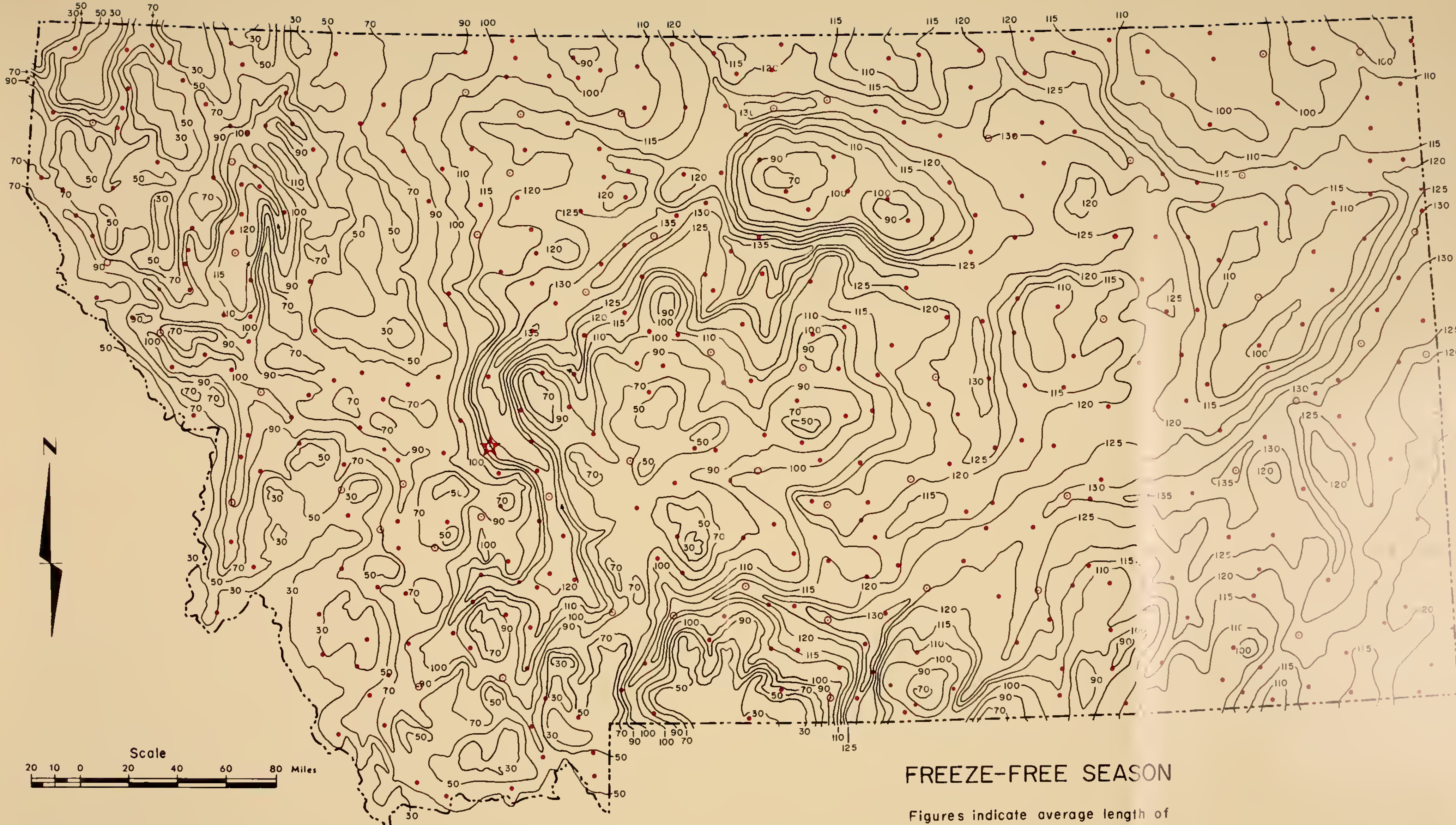
SOURCE:
J. M. Caprio, Professor and Agricultural Climatologist
Agricultural Experiment Station,
Montana State University
Bozeman, Montana

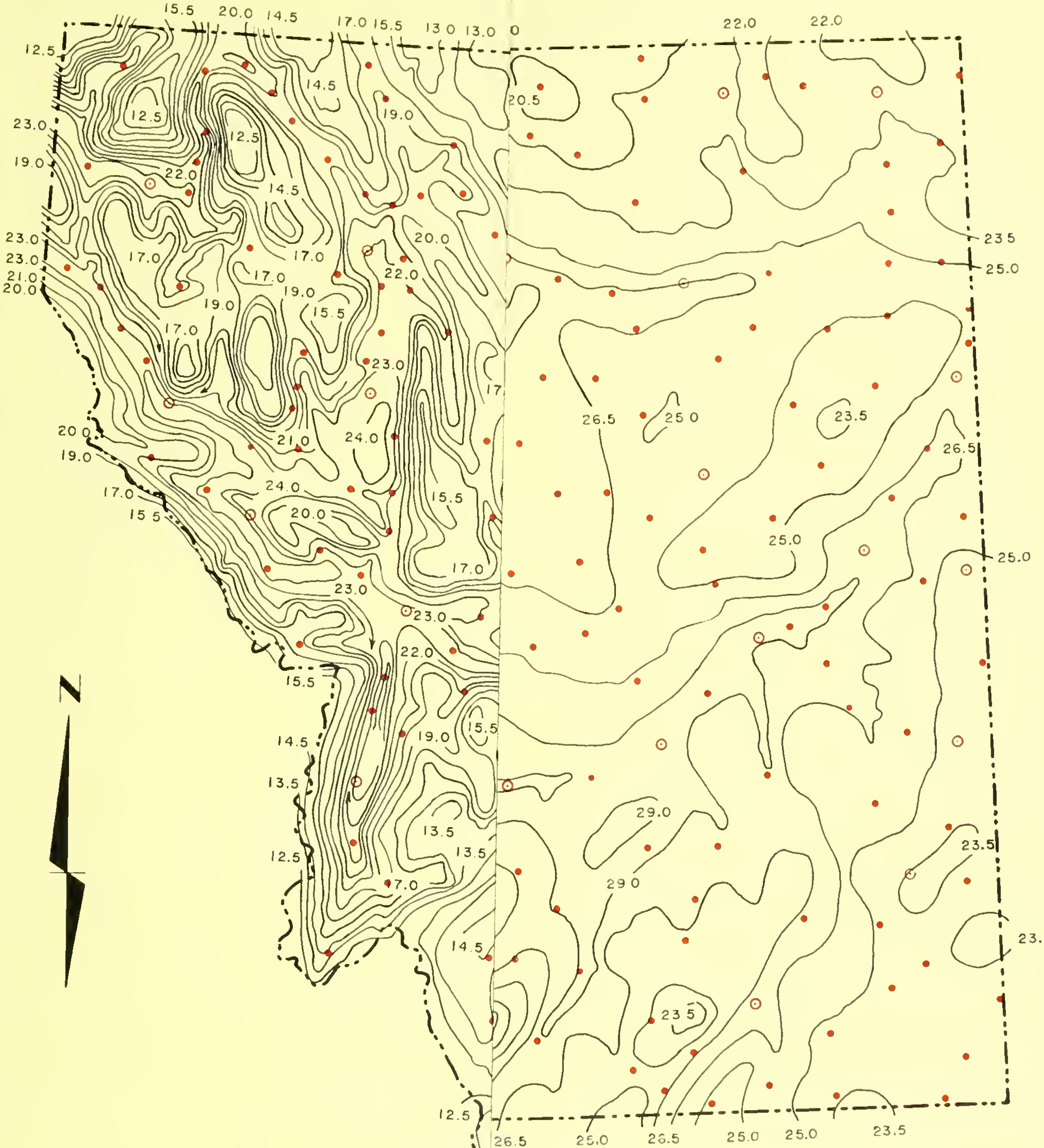


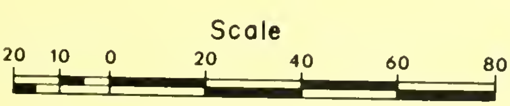
FREEZE-FREE SEASON

Figures indicate average length of freeze-free season in days.

SOURCE:
J. M. Caprio, Professor and Agricultural Climatologist
Agricultural Experiment Station,
Montana State University
Bozeman, Montana

★ Capital
⊙ County Seats
• Towns





RANSPIRATION

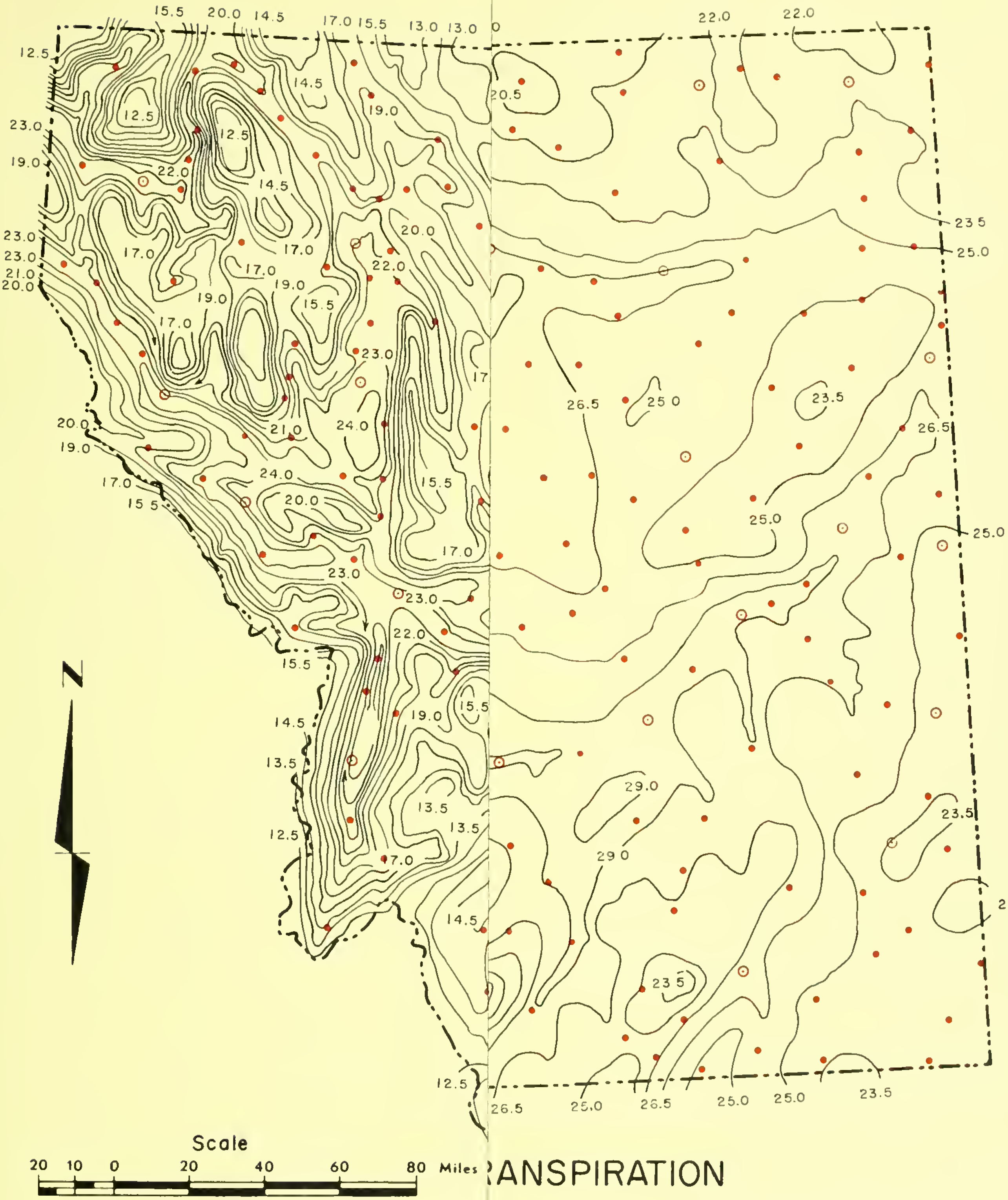
ted average annual accumu-
ular 251 and Bulletin 607)

st of Divide
TU x 10^{-5}

— 25.0
— 24.0
— 23.0
— 22.0
— 21.0
— 20.0
— 19.0
— 17.0
— 15.5
— 14.5
— 13.5
— 12.5

SOURCE:

Joseph M. Caprio
Plant & Soil Science Dept
Montana State University
Bozeman, Montana
May 15, 1973



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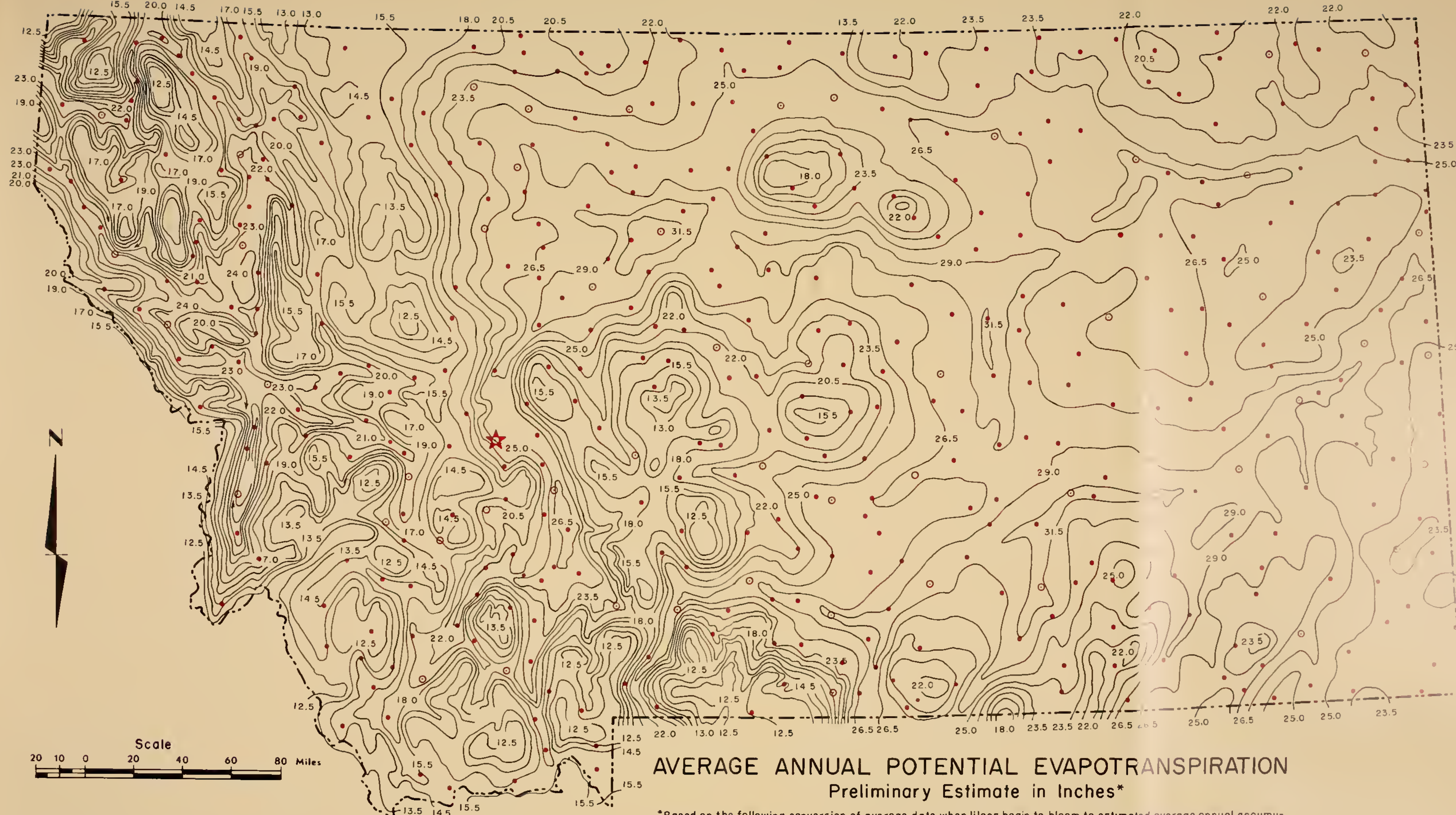


AVERAGE ANNUAL POTENTIAL EVAPOTRANSPIRATION

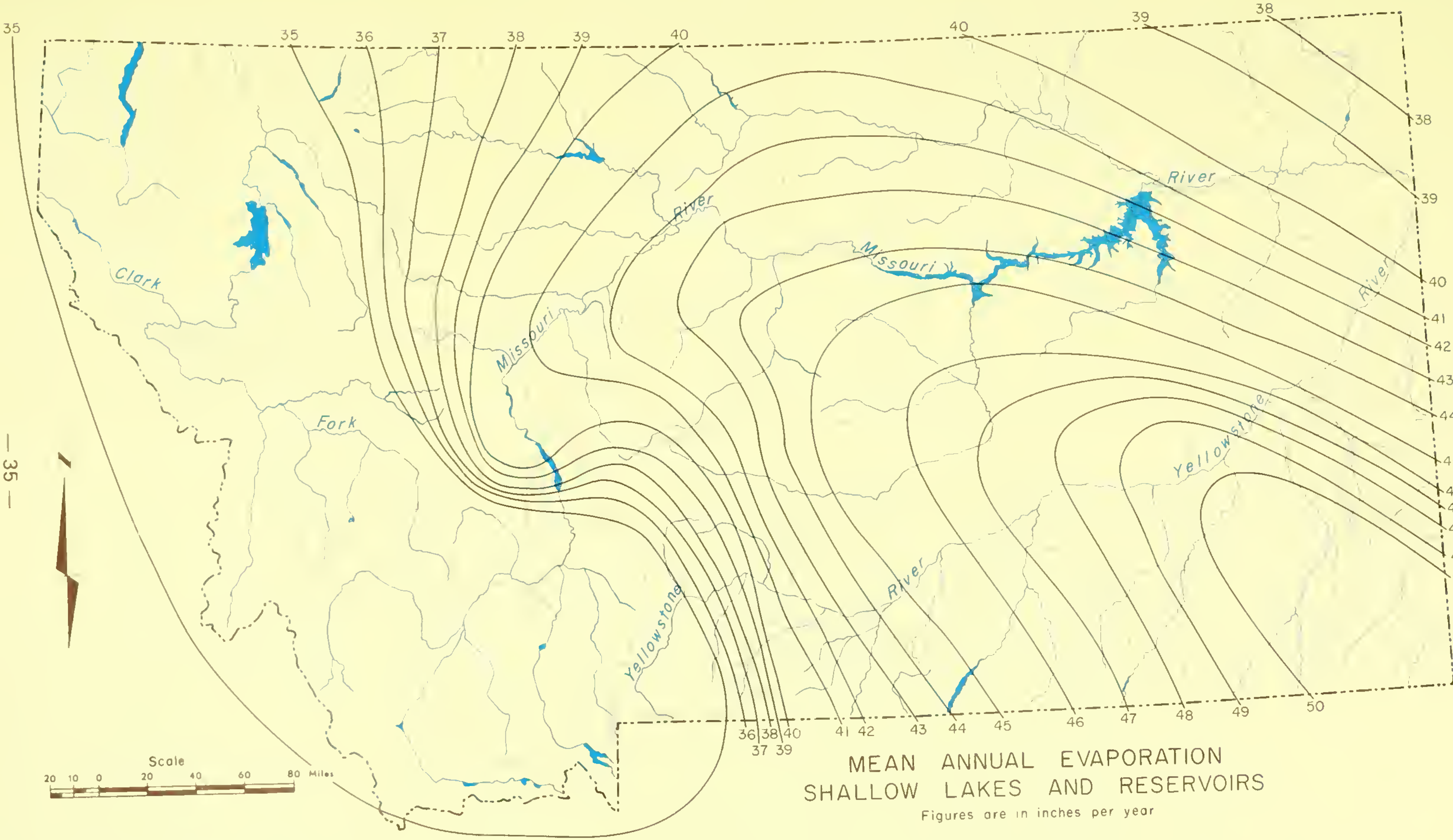
Preliminary Estimate in Inches*

*Based on the following conversion of average date when lilacs begin to bloom to estimated average annual accumulation of Solar Thermal Units x 10^{-5} (See Montana Agricultural Experiment Station Circular 251 and Bulletin 607)

Average Date of Begin Bloom	East of Divide STU x 10^{-5}	West of Divide STU x 10^{-5}
May 12	31.5	25.0
May 15	29.0	24.0
May 18	26.5	23.0
May 21	25.0	22.0
May 24	23.5	21.0
May 27	22.0	20.0
May 30	20.5	19.0
June 4	18.0	17.0
June 9	15.5	15.5
June 14	14.5	14.5
June 19	13.5	13.5
June 24	12.5	12.5

★ Capital
⊙ County Seats
• Towns

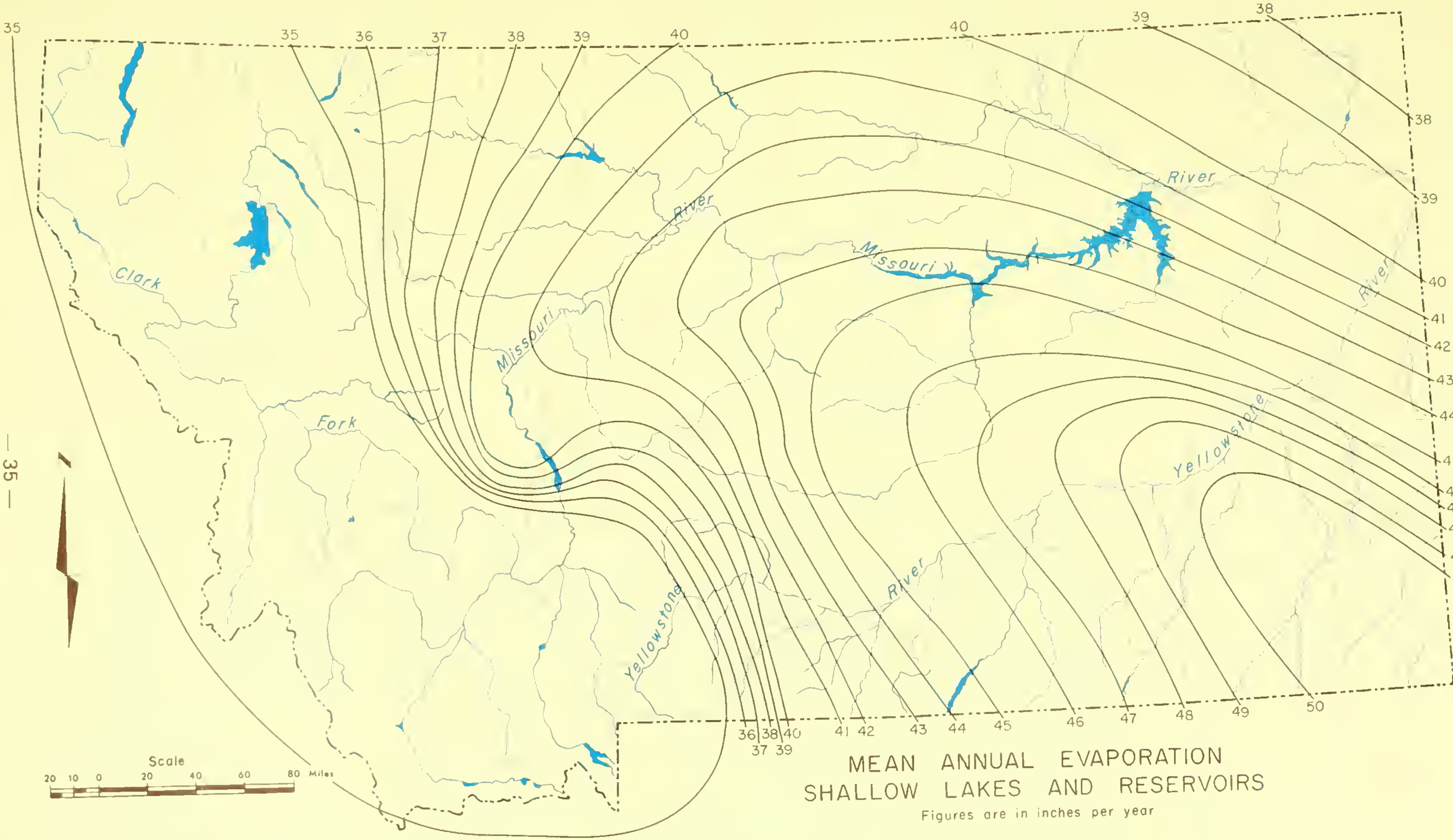
SOURCE:
Joseph M. Caprio
Plant & Soil Science Dept
Montana State University
Bozeman, Montana
May 15, 1973



MEAN ANNUAL EVAPORATION
SHALLOW LAKES AND RESERVOIRS

Figures are in inches per year

SOURCE
Soil Conservation Service
U S Department of Agriculture



MEAN ANNUAL EVAPORATION
SHALLOW LAKES AND RESERVOIRS
Figures are in inches per year

SOURCE
Soil Conservation Service
U. S. Department of Agriculture

HYDROLOGIC SUBDIVISIONS

Three major river systems in North America have tributaries along the Continental Divide in western Montana.

East of the divide, the Missouri River has its headwaters in extreme southwestern Montana and flows northerly and then easterly through the state. It is joined just inside North Dakota by the Yellowstone, which flows from Yellowstone National Park across southeastern Montana, and by the Little Missouri River, which flows across extreme southeastern Montana. The water from these streams eventually reaches the Gulf of Mexico via the Mississippi River.

Across the divide, water from two basins in western Montana ultimately drains into the Pacific Ocean. The Clark Fork of the Columbia flows northwesterly from near Butte, adding to its flow the waters of such streams as the Blackfoot, Bitterroot, and Flathead. The Kootenai River originates in Canada, flows south into Montana, turns abruptly west near Libby, and flows through Idaho back into Canada, where it eventually joins the Columbia River.

The third river system originates in Glacier National Park and flows north through Canada to Hudson Bay. The St. Mary River of the Saskatchewan River Basin is the principal stream originating in this area.

Statistics concerning the drainage areas of the major river basins in Montana are presented in Table 4.

For this report and the State Water Plan, the state has been divided into three major study areas: the Columbia, Missouri, and Yellowstone River Basins (see Major Study Areas Map on the opposite page). The Columbia includes everything west of the Continental Divide (Kootenai and Clark Fork Basins), figures for the Missouri will often include those for the St. Mary Drainage, and Yellowstone Basin data will, where possible, include statistics on the Little Missouri Basin.

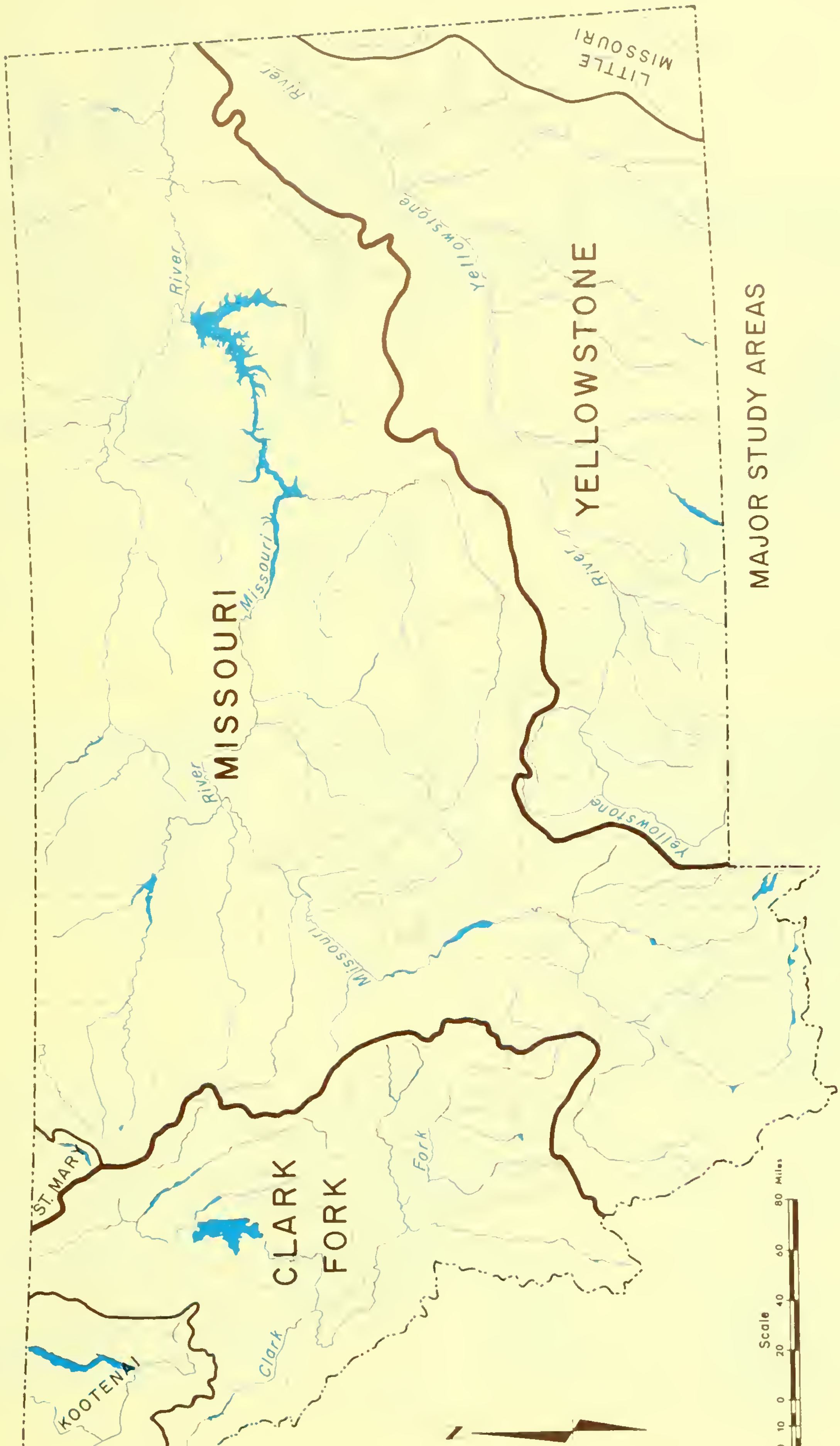
TABLE 4

DRAINAGE BASIN AREAS

River Basin*	TOTAL DRAINAGE AREA		DRAINAGE AREA IN MONTANA		
	Area (sq. mi.)	Percentage in Montana	Area (sq. mi.)	Percentage of Montana	Percentage of Montana's Water
Columbia	259,500	10%	25,400	17%	59%
Missouri	523,900	16%	82,000	56%	17%
Yellowstone	71,000	50%	35,600	24%	21%
Little Missouri**	8,500	40%	3,400*	2%	1%
Hudson Bay	Unknown	- - -	600	1%	2%
			147,000	100%	100%

*The Columbia and Missouri River Basins include parts of Canada, the Yellowstone River Basin includes part of Wyoming, the Little Missouri River Basin includes parts of Wyoming and North and South Dakota

**Includes the Belle Fourche River Basin in southeast Montana


MAJOR STUDY AREAS
MISSOURI
YELLOWSTONE
CLARK FORK
KOOTENAI
ST. MARY
LITTLE MISSOURI
Missouri River
Yellowstone River
Clark Fork
Scale
0 20 40 60 80 Miles

WATER RESOURCES

Montana's water is one of the state's greatest resources. Water plays an essential role in agriculture, in industry, in power production, in the home, and in recreation.

SURFACE WATER

Quantity

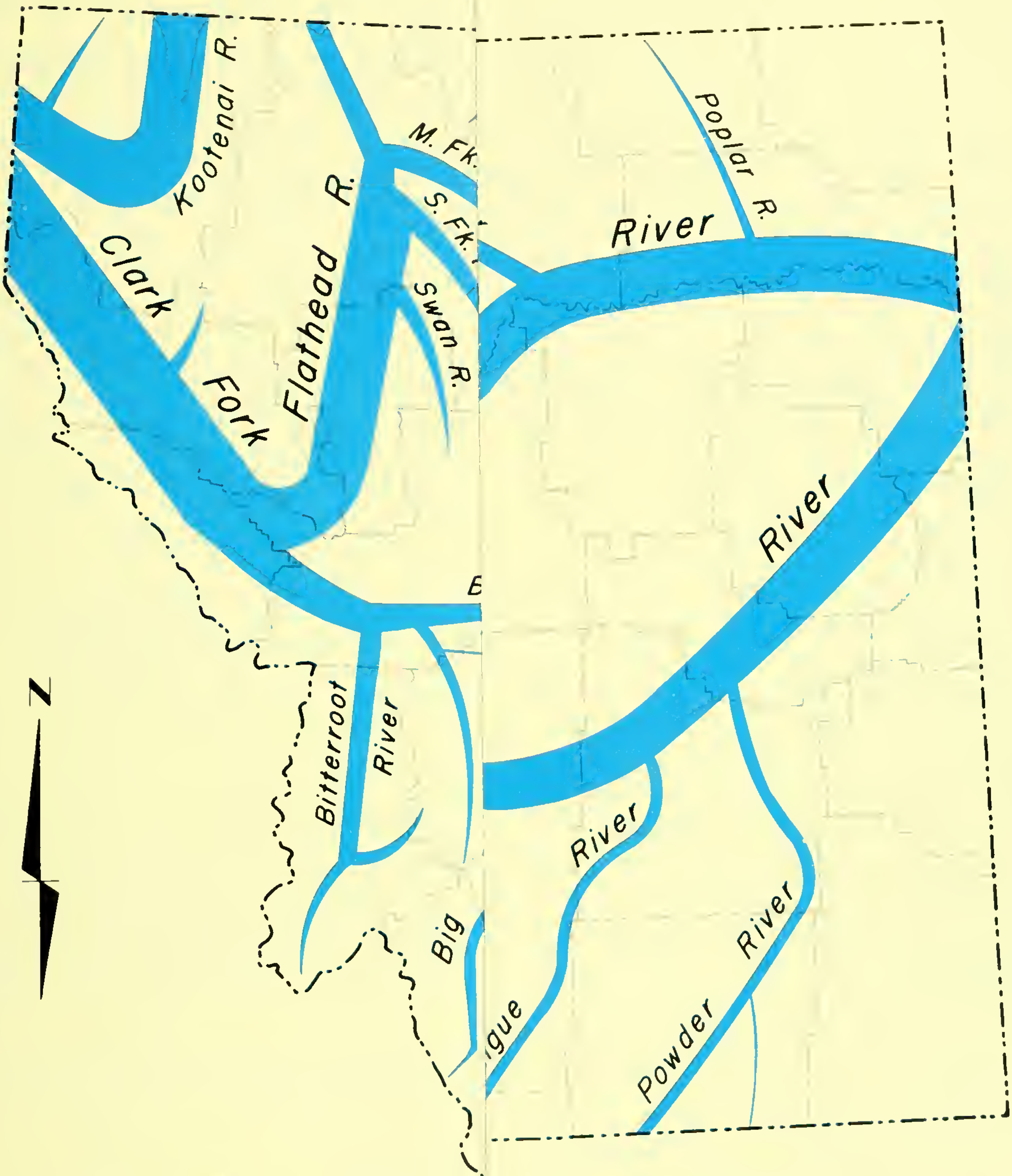
Surface water, defined as the water which rests upon or flows over the earth's surface, is an intrinsic part of the social, economic, and environmental values of Montana. Because most of the surface water originates within Montana as precipitation, the state does not have to rely primarily upon inflow from other areas.

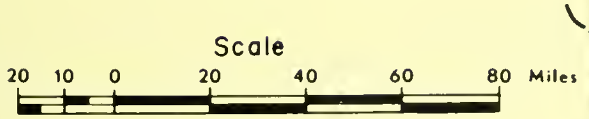
Table 5 (page 41) shows the relationship between river basin inflow and the amount of water originating in the state. Over forty-three million acre-feet of water flows from the state each year, 65 per cent of which originates in Montana.

The map on the opposite page portrays the relative amount of mean annual streamflow in larger streams throughout the state. The maximum discharge, mean annual flow, minimum daily flow, and average monthly flow of most of these streams are presented in the Appendix, "Streamflow Hydrographs."

The seasonal and annual dependability of streamflow is largely dependent on runoff. Mean annual runoff in the state ranges from less than .25 inch to more than 100 inches. Though nearly half the state discharges less than one inch per year, mountainous areas along the Continental Divide discharge a high amount of runoff. Melting of snowpack that accumulates in the high mountains during the winter begins in April and usually reaches a peak in late May or early June. Runoff is essentially completed in July, after which normal summer flows may be modified by diversion or by summer rains.

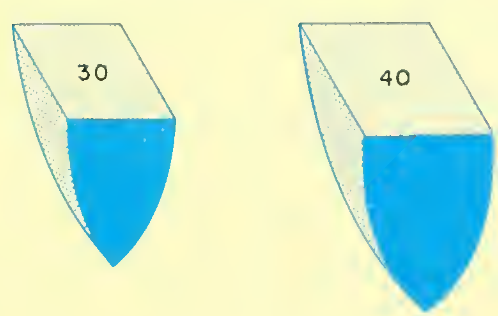
STREAM-GAGING STATION ON NORTH MEADOW CREEK, NORTHWEST OF ENNIS



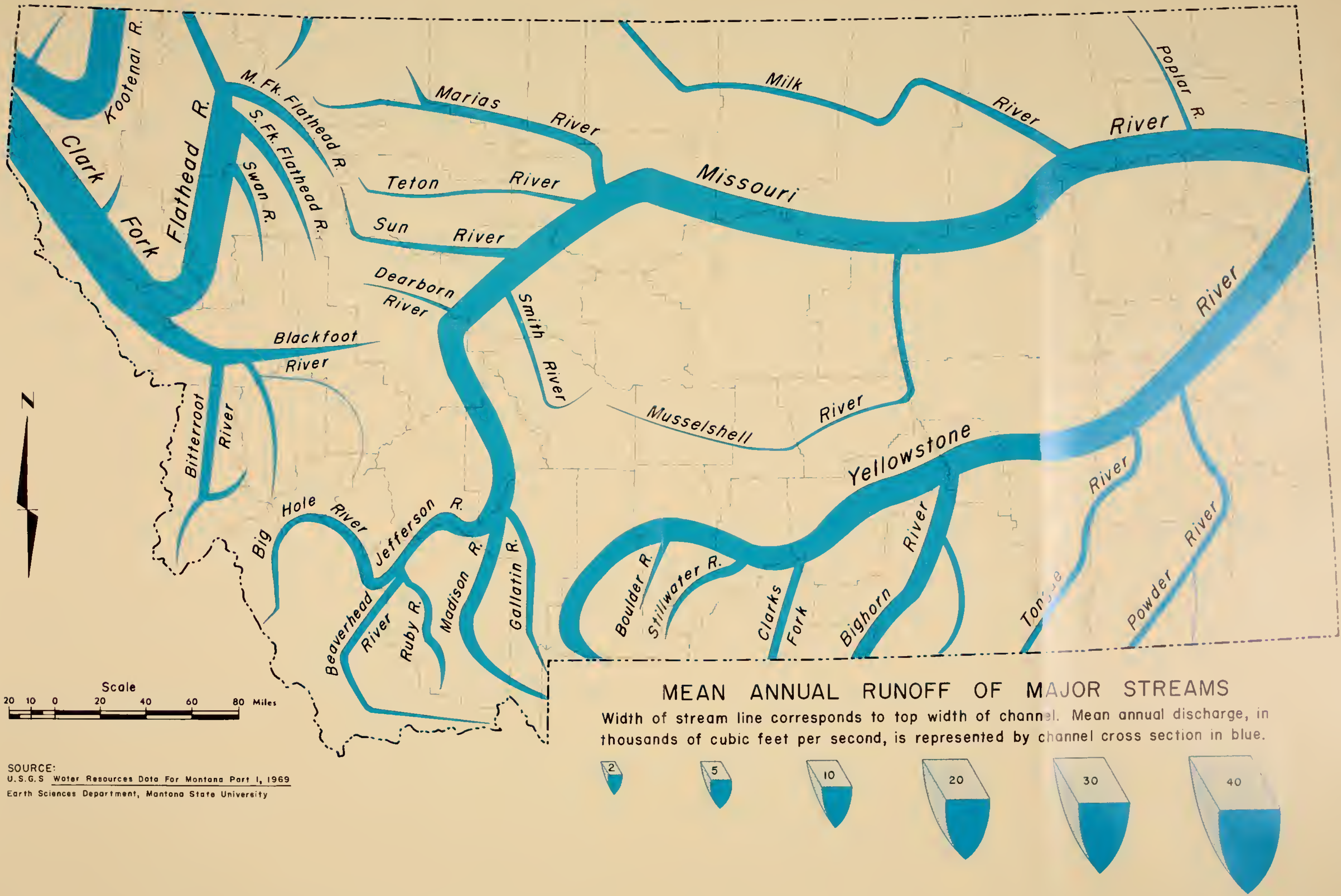


AJOR STREAMS

el. Mean annual discharge, in
:hannel cross section in blue.



SOURCE:
U.S.G.S. Water Resources Data For Montana Part I, 196
Earth Sciences Department, Montana State University



MEAN ANNUAL RUNOFF OF MAJOR STREAMS

Width of stream line corresponds to top width of channel. Mean annual discharge, in thousands of cubic feet per second, is represented by channel cross section in blue.

SOURCE:
U.S.G.S Water Resources Data For Montana Part I, 1969
Earth Sciences Department, Montana State University

TABLE 5

RIVER BASIN INFLOW AND OUTFLOW (in Acre-Feet)

Drainage	Inflow	Originating in the State	Leaving the State	Percentage Originating in State
Clark Fork	703,500	15,216,500	15,920,000	95
Kootenai	7,600,000	2,520,000	10,120,000	25
Missouri	893,600*	6,431,400	7,325,000	88
Hudson Bay	0	989,150	989,150**	100
Yellowstone	6,227,000	3,126,000	9,353,000	33
Little Missouri	55,930	132,500	188,430	70
TOTAL	15,480,030	28,415,550	43,895,580	65

*U.S. Department of the Interior 1964b and 1969.
**U.S. Department of the Interior 1964a.
SOURCE. U.S. Department of the Interior 1972, except as otherwise noted.

Streams originating in the plains area are usually extremely low or not flowing during the winter. Snow and channel ice accumulated during the winter normally melt in late March or early April and may produce the peak flow of the year. Recession from the peak is rapid, and subsequent increases in flow are dependent upon rain of sufficient intensity and duration to cause surface runoff. Streams in the foothills and plains often cease flowing during the hottest part of the year; however, it is possible for these streams to reach their peak flow during the summer following isolated cloudbursts.

Montana's surface water resource — streams, lakes, and reservoirs — is illustrated by the Major Water Features Map on page 43. Information concerning natural lakes, stock ponds, and resevoirs is also presented in Table 6. With few exceptions, these are estimates; exact figures are not known.

TABLE 6

SURFACE WATER AREA

	Number	Surface Area (acres)
Lakes	1,500-1,700	34,000
Stock Ponds	61,000	147,000
Reservoirs of 50 to 5,000 acre-feet	1,000-1,200	87,000
Reservoirs over 5,000 acre-feet	67	632,000
	TOTAL	900,000

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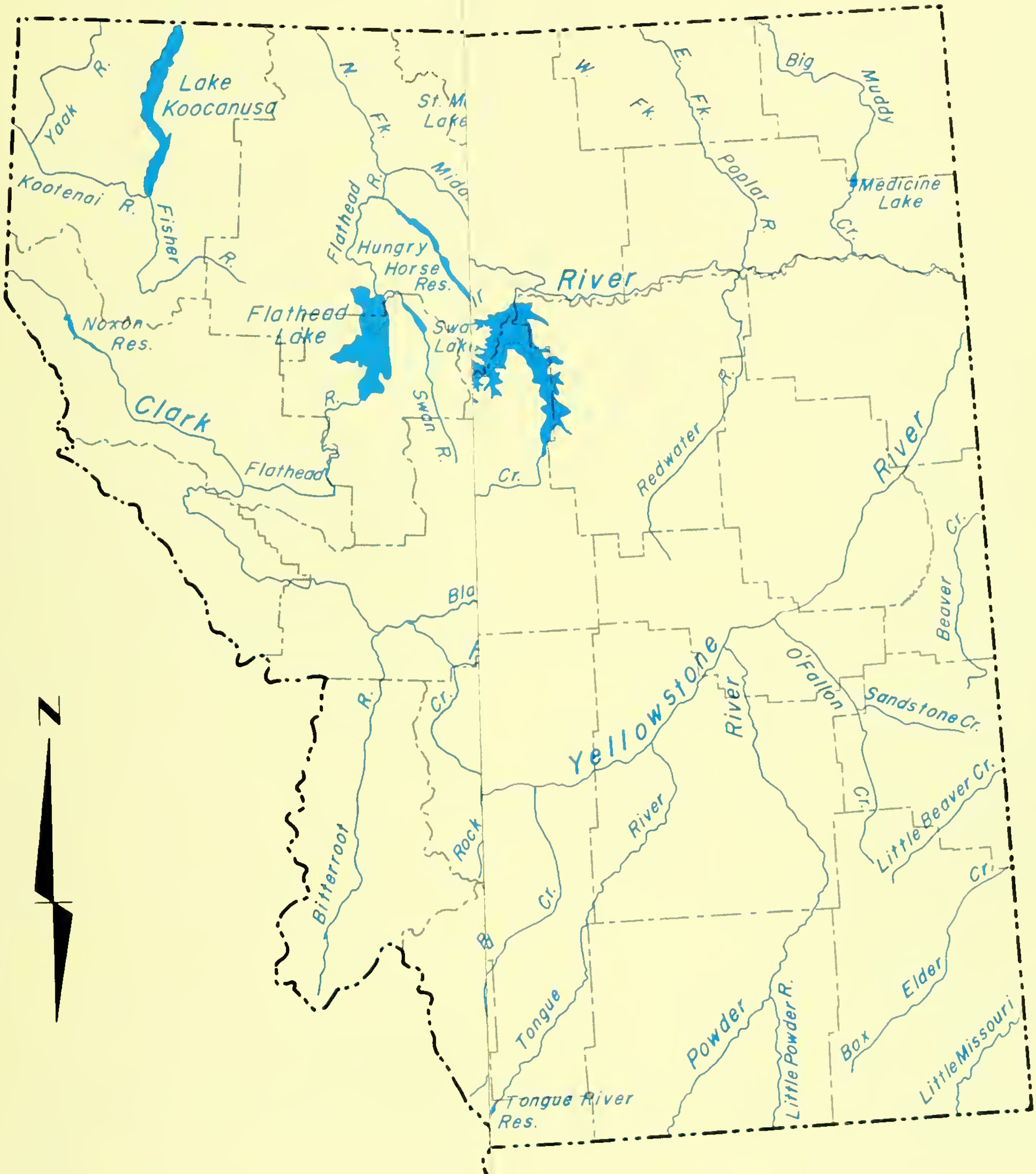
	TOTAL	900,000

There are more than 1,500 natural lakes in Montana, mainly in the mountainous areas of western and south-central Montana. The largest is Flathead Lake (126,000 acres), located in northwestern Montana. While still relatively unchanged, Flathead was increased in storage capacity by the construction of Kerr Dam in 1938. For this reason, Flathead Lake is considered a reservoir in this report.

Reservoirs in Montana vary in size from small stock-water ponds to the immense Fort Peck Reservoir. Information concerning the largest reservoirs is summarized in Table 7 (page 45). As used there and in subsequent tables, "Total Storage" indicates the capacity for which the reservoir was designed. Often the total storage is less than the actual storage (if the reservoir was originally a natural lake) or the maximum capacity of the reservoir. "Active Storage" is generally the amount of water which may be removed through the dam. The combined total storage of these larger reservoirs is over 38.5 million acre-feet.

LOOKING NORTH ON FLATHEAD LAKE



Scale

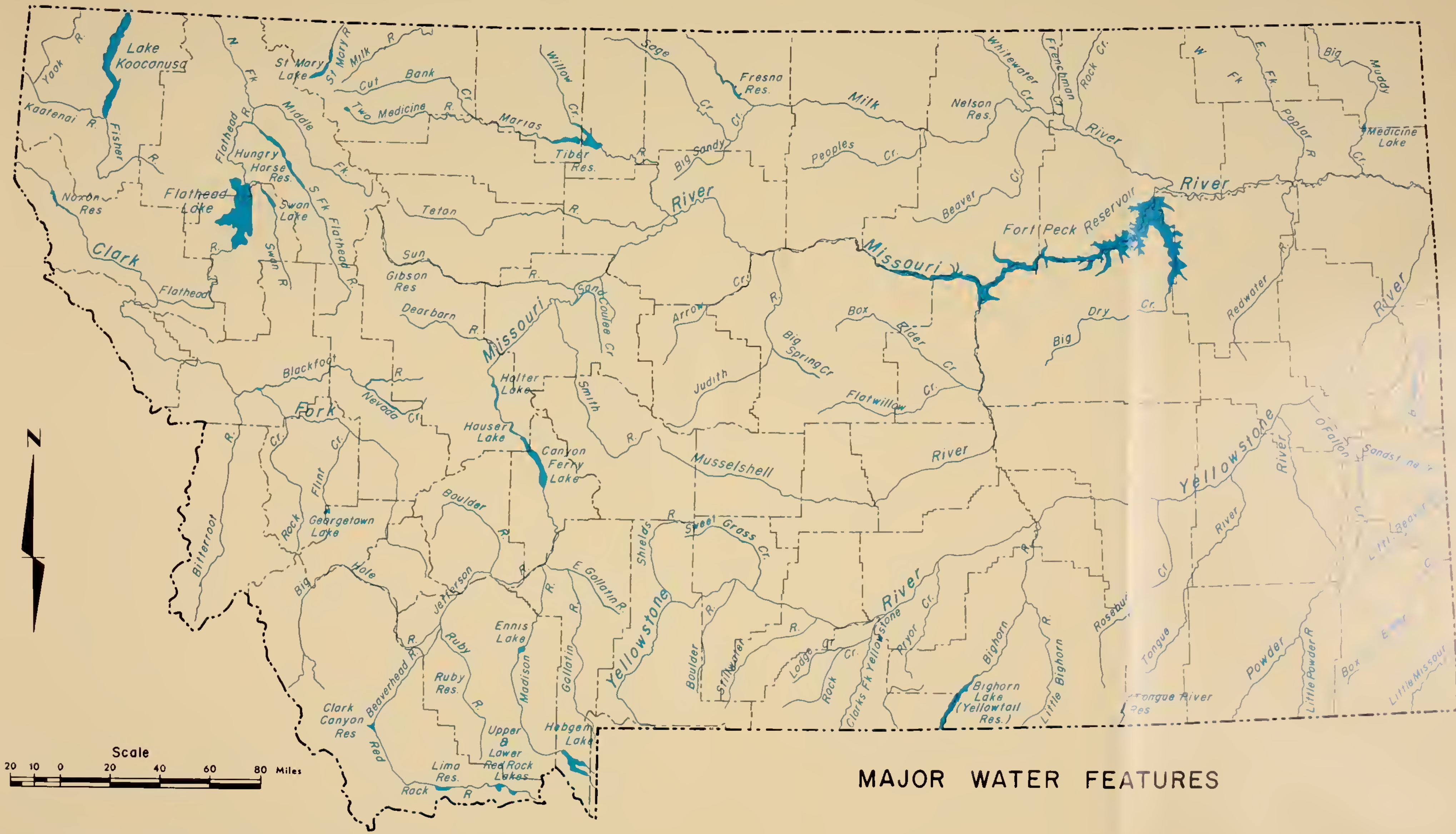
20 10 0 20 40 60 80 Miles

ATURES

SOURCE:

U. S. G. S. Major, Sub-Major & Minor Dr

Earth Sciences Department, Montana S



MAJOR WATER FEATURES

SOURCE:
U. S. G. S. Major, Sub-Major & Minor Drainage Basins
Earth Sciences Department, Montana State University

TABLE 7

MONTANA RESERVOIRS HAVING A TOTAL CAPACITY OF 5,000 ACRE-FEET OR MORE

Basin	Number of Reservoirs	Total Storage (acre-feet)	Active Storage (acre-feet)	Surface Area (acres)
Columbia	22	11,978,365	9,811,057	223,293
Missouri	38	25,017,221	18,633,565	384,411
Yellowstone	7	1,537,429	1,517,030	24,130
TOTAL	67	38,533,015	29,961,652	631,834

Only 30 of the larger reservoirs were originally constructed for multi-purpose benefits, including power generation, flood control, municipal and industrial water supply, fish and wildlife, and recreation, as well as irrigation storage. The majority of reservoirs in Montana were constructed as single purpose projects for either irrigation or stock-water storage. Incidental flood control, fish and wildlife, and recreational benefits have increased the value of these projects over the years.

Storage from flood control and power generation reservoirs follows a pattern of release during the late summer, fall, and winter months and storage during the spring and early summer. These releases have variable short-term effects on river flow. The changes in discharge due to power demands are abrupt, and, when power generation is lessened, flows may be low. Irrigation water is supplied at a fairly constant rate from several reservoirs during April through September, while most recreational use takes place during the summer. Recreation on most reservoirs is often adversely affected during late summer because of drawdown of reservoir levels for downstream water demand.

Farm or stock-water ponds provide a significant amount of water storage within the state. Records of the number of farm ponds are incomplete, but a conservative estimate by the Soil Conservation Service places the number at 61,100 ponds with a combined storage of 586,560 acre-feet. Although an extremely large volume of water both flows from and is stored within the state, it is not evenly distributed. These farm or stock-water ponds are especially important in that many are located in the more arid sections of the state and provide late-season water for stock, domestic, and agricultural use.

RUBY RIVER RESERVOIR, NEAR ALDER

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RUBY RIVER RESERVOIR, NEAR ALDER

PAINTED ROCKS LAKE, WEST FORK BITTERROOT RIVER

Columbia River Basin. The Columbia River Basin includes all land in Montana west of the Continental Divide. It is this portion of the state that could be best described as "water rich." While containing only 17 per cent of the land mass of Montana, this basin is the source of 59 per cent of the state's total surface water outflow.

As in the other two major basins in Montana, seasonal and yearly flows vary considerably. The two largest streams are the Clark Fork and the Kootenai Rivers. The Clark Fork has an average annual flow of 15,920,000 acre-feet near Cabinet, Idaho, at the border, as compared to the Kootenai's average outflow of 10,120,000 acre-feet per year. Major tributaries of the Clark Fork are the Bitterroot, Blackfoot, and Flathead Rivers. The majority of the flow of the Kootenai, 7,600,000 acre-feet, originates in Canada. The Yaak and Fisher Rivers are the Kootenai's major tributaries in Montana

The Clark Fork subbasin contributes about 14 inches of runoff in an average year. The upper Clark Fork Drainage above Missoula lies in the precipitation shadow of the Bitterroot Range and contributes only about six inches of runoff per year. When compared to the nearly 27 inches of runoff from the area drained by the South Fork of the Flathead River, the wide variation of water distribution even within the same subbasin becomes obvious. The Kootenai drainage contributes only about 11 inches of runoff per year in Montana. A large part of the basin's total flow results from the 18 inches of runoff contributed by that portion of the basin located in Canada.

Table 8 lists 22 large reservoirs with a total storage of almost 12 million acre-feet in the Columbia River Basin in Montana. Lake Koocanusa, with a storage capacity of 5,850,000 acre-feet, provides the largest usable storage of the reservoirs within the basin. Hungry Horse Reservoir and Flathead Lake are the other two major storage sites, with capacities of 3,468,000 and 1,791,000 acre-feet of total storage, respectively.

There is little information available on the number or size of smaller farm and stock-water ponds in the basin. However, it is estimated that the Columbia Basin has fewer of such impoundments than either the Missouri or the Yellowstone Basin because fewer are necessary; the Columbia Basin enjoys a more constant water supply throughout the year.

TABLE 8

COLUMBIA BASIN RESERVOIRS HAVING A TOTAL CAPACITY OF 5,000 ACRE-FEET OR MORE

Name	Stream	Total Storage (acre-feet)	Active Storage (acre-feet)	Surface Area (acres)	Purposes*
Ashley Lake	Ashley Creek	20,000	20,000	3,000	I
East Fork	East Fork Rock Creek	16,040	16,040	442	I
Flathead Lake	Flathead River	1,791,000	1,219,000	126,000	P
Georgetown Lake	Flint Creek	31,040	31,040	3,000	M, P, FW
Hubbart	Little Bitterroot River	12,120	12,120	460	I
Hungry Horse	South Fork Flathead River	3,468,000	2,982,000	23,750	FC, I, P
Kicking Horse	Offstream Crow Creek	8,420	8,350	785	I
Lake Como	Rock Creek	36,693	34,920	940	I
Lake Koocanusa	Kootenai River	5,850,000	4,965,000	46,500	FC, P, FW
Little Bitterroot Lake	Little Bitterroot River	26,400	26,400	2,994	I
Lower Crow	Crow Creek	10,350	10,350	340	I
Lower Jocko	Middle Fork Jocko River	7,580	6,380	116	I
Lower Willow Creek	Willow Creek	5,100	4,819	170	I
McDonald	Post Creek	10,600	8,220	200	I
Mission	Mission Creek	7,250	7,250	290	I
Nevada Creek	Nevada Creek	12,640	12,628	375	I
Ninepipe	Offstream Flathead River	14,870	14,870	1,600	I
Noxon Rapids	Clark Fork	495,600	334,600	7,900	P
Pablo	Offstream Flathead River	29,600	27,100	2,040	I
Painted Rocks	West Fork Bitterroot River	32,362	31,700	655	I
Tabor (St. Mary Lake)	Dry Creek	23,300	23,300	286	I
Thompson Falls	Clark Fork	69,400	14,970	1,450	P
Total		11,978,365	9,811,057	223,293	

*Purposes — I — Irrigation, P — Power, M — Municipal, FW — Fish & Wildlife, FC — Flood Control

CITADEL ROCK, MISSOURI RIVER BELOW VIRGELLE

Missouri River Basin. The Missouri River Basin is by far the largest of the three major basins of the state, containing approximately 56 per cent of the land yet only 17 per cent of the water. Over a forty-year period, the Missouri has discharged an average of 7,325,000 acre-feet of water per year from the state — less than the Yellowstone, Clark Fork of the Columbia, or Kootenai Rivers.

Above Three Forks, the Jefferson, Madison, and Gallatin Rivers form the Missouri. Other tributaries to the Missouri, arising in the mountain and foothill regions or flowing across Montana's plains, include the Dearborn, Smith, Sun, Teton, Marias, Judith, and Musselshell Rivers. The Milk River and its tributaries, adjacent to Glacier Park, flow north into Canada, re-enter Montana in northwestern Hill County, and drain into the Missouri just below Fort Peck Dam.

Aside from the water arising in Yellowstone National Park, the only inflow from out of state into the Missouri River system is from the Milk and Poplar Rivers and their tributaries arising in Canada. Nearly 448,000 acre-feet of water per year enters the Missouri drainage from Canada, accounting for only six per cent of the outflow of the Missouri River at Culbertson.

Average annual runoff in the mountainous one-third of the basin varies from two inches in the foothills to 20 inches in the higher mountain areas. Even so, most of the basin is semiarid. In the eastern two-thirds of the basin, the glaciated and sedimentary plains, an annual runoff as low as 0.5 inch per year is not uncommon.

Fort Peck Reservoir, with a total storage capacity of 19,410,000 acre-feet on the mainstem of the Missouri River, is by far the largest reservoir in the state and is the fifth largest in the United States. Canyon Ferry and Tiber are the next largest reservoirs in the Missouri River Basin, with total storage capacities of 2,051,000 and 1,368,000 acre-feet, respectively. Table 9 lists 38 reservoirs in the basin with storage capacities of 5,000 acre-feet or more. The total storage of these reservoirs is over 25,000,000 acre-feet.

In addition to the larger impoundments, there are several hundred smaller reservoirs in the basin providing irrigation, flood prevention, and stock-water benefits.

The Hudson Bay drainage in Montana consists of the Waterton, Belly, and St. Mary Rivers, arising in Glacier National Park and flowing northward to the Saskatchewan River in Canada. Each year, these three rivers and other small tributaries, draining less than one per cent of Montana's land area, discharge an average of 989,150 acre-feet, or two per cent of the state's water to Canada. Lake Sherburne in Glacier Park provides 66,200 acre-feet of storage on Swiftcurrent Creek, and the St. Mary Canal conveys an average seasonal flow of 142,600 acre-feet to the North Fork of the Milk River in Montana, helping provide for the extensive irrigation between Havre and Glasgow.

TABLE 9

MISSOURI BASIN RESERVOIRS HAVING A TOTAL CAPACITY OF 5,000 ACRE-FEET OR MORE

Name	Stream	Total Storage (acre-feet)	Active Storage (acre-feet)	Surface Area (acres)	Purposes*
Ackley Lake	Offstream Judith River	6,140	5,815	250	I
Bair	North Fork Musselshell River	7,030	7,010	252	I
Bynum	Offstream Teton River	75,000	74,500	4,120	I
Canyon Ferry	Missouri River	2,051,000	2,043,000	35,200	FC,I,FW,P
Clark Canyon	Beaverhead River	328,900	328,900	10,000	FC,I,FW
Deadman's Basin	Offstream Musselshell River	76,900	72,220	2,042	I
Delmoe Lake	Pipestone Creek	6,600	6,600	479	I
Ennis Lake	Madison River	42,060	42,060	3,800	P
Eureka	Teton River	5,500	5,000	400	I
Fort Peck	Missouri River	19,410,000	13,915,000	245,000	M,FC,P,I
Four Horns	Badger Creek	20,000	19,250	897	I
Frenchman	Frenchman Creek	7,010	7,010	806	I
Fresno	Milk River	129,000	127,200	5,757	FW,M,I,FC
Gibson	Sun River	105,000	104,800	1,360	I,FW
Hauser Lake	Missouri River	98,230	51,420	3,800	P
Hebgen Lake	Madison River	384,800	377,500	12,668	P
Holter Lake	Missouri River	240,420	81,920	4,800	P
Kipps Lake	Offstream Willow Creek	5,009	4,500	335	L,I
Lake Francis	Offstream Dupuyer & Birch Creek	117,000	111,900	5,536	I
Lake Helena	Missouri River	10,450	10,450	610	I,M
Lake Sherburne	Swiftcurrent Creek	66,200	66,200	1,730	FW,I
Lima	Red Rock River	84,050	84,050	6,400	I
Lower Two Medicine Lake	Two Medicine Creek	13,500	11,880	806	I
Martinsdale	Offstream So. Fork Musselshell River	23,185	23,105	1,050	I
Middle Creek	Middle or Hyalite Creek	8,030	7,821	223	M,I
Morony	Missouri River	13,260	7,900	300	P
Nelson	Offstream Milk River	85,450	66,800	4,560	FW,I
Nilan	Offstream Smith & Ford Creeks	10,990	10,092	535	I
North Fork Smith River	North Fork Smith River	11,600	11,550	335	I
Petrolia	Flatwillow Creek	9,192	8,822	515	I
Pishkun	Offstream North Fork Sun River	48,450	32,050	1,550	I
Ruby River	Ruby River	38,850	38,500	970	I
Swift	Birch Creek	30,015	29,980	455	I
Tiber	Marias River	1,368,000	762,000	22,180	FW,I,FC,M
Warhorse Lake	Offstream Ford Creek	23,800	23,800	1,560	I
Whitetail	Whitetail Creek	6,200	4,000	830	I
Willow Creek	Offstream Sun River	32,400	32,230	1,450	I,FW
Willow Creek	Willow Creek	18,000	17,730	850	I
Total		25,017,221	18,633,565	384,411	

*Purposes — I — Irrigation, FC — Flood Control, FW — Fish & Wildlife, P — Power, M — Municipal, L — Livestock

Yellowstone River Basin. The Yellowstone River Basin is divided nearly equally between the states of Montana and Wyoming. The Yellowstone arises in Yellowstone National Park and northern Wyoming and flows northeasterly to join the Missouri just inside North Dakota. The basin in Montana contains 24 per cent of the state's land surface and yields 21 per cent of Montana's water. At their point of confluence, the Yellowstone yields 22 per cent more annual flow than the Missouri, though it drains 14 per cent less area.

The Yellowstone River receives over one-half of its total flow from tributaries rising in the mountain ranges upstream from Billings. These tributaries include those in Yellowstone National Park as well as the Shields, Boulder, Stillwater, and Clarks Fork Yellowstone Rivers. The Bighorn, Tongue, and Powder Rivers, originating in the mountains of Wyoming, provide much of the remaining flow.

The Yellowstone Basin is similar in many respects to the Missouri Basin; much of its plains area is classified as semiarid. As a result, the stream runoff follows the same general pattern exhibited in the Missouri Basin: relatively high total runoff from mountain streams, and low total runoff from plains streams.

The discharge of the major tributaries of the Yellowstone is small when compared to the total drainage area. The Powder River, for example, has an average flow of only 600 cubic feet per second (cfs) from a drainage area of 13,194 square miles. Almost no flow has been recorded on numerous occasions, and on February 19, 1943, the stream discharge reached an all-time recorded high of 31,000 cfs.

Seven reservoirs in the Yellowstone River Basin in Montana each have a total storage capacity of 5,000 acre-feet or more. Yellowtail Reservoir, with a total capacity of 1,375,000 acre-feet, is the largest in the basin. The second largest in the Montana portion of the basin is the Tongue River Reservoir, constructed by the state and containing 69,439 acre-feet of water. Together, the seven reservoirs provide over 1.5 million acre-feet of water storage.

In addition to the major projects listed in Table 10, several hundred smaller irrigation projects and probably as many stock-water ponds are scattered throughout the basin.

The Little Missouri River Basin in Montana consists of the Little Missouri River, which passes through the southeastern corner of the state, and Box Elder, Little Beaver, and Beaver Creeks, which are tributaries arising in Carter, Fallon, and Wibaux Counties. These four streams discharge 188,430 acre-feet of water per year to North Dakota, 132,500 acre-feet of which originates in Montana. The basin includes 2 per cent of Montana's land area, but accounts for less than 1 per cent of the water leaving the state.

Quality

Montana's surface waters are generally rated from good to excellent for both chemical and bacterial quality. The principal exceptions are local bacterial contamination below municipal discharges, chemical and toxicity problems below mining and petroleum operations, and suspended sediment from periods of high stream runoff, geologic erosion, and improper land use activities. The subject of surface water quality is further discussed in **Volume Two of The Framework Report**.

TABLE 10

YELLOWSTONE BASIN RESERVOIRS HAVING A TOTAL CAPACITY OF 5,000 ACRE-FEET OR MORE

Name	Stream	Total Storage (acre-feet)	Active Storage (acre-feet)	Surface Area (acres)	Purposes*
Cooney	Red Lodge Creek	24,190	24,190	790	I
Lake Adam	Sweet Grass Creek	11,000	11,000	585	I
Lake Wolvoord	Sweet Grass Creek	14,000	14,000	768	I
Mystic Lake	West Rosebud Creek	20,800	20,800	440	P
Tongue River	Tongue River	69,439	68,040	3,497	I
Lodge Grass	Willow Creek	23,000	23,000	750	I
Yellowtail	Bighorn River	1,375,000	1,356,000	17,300	I,FC,P,FW
Total		1,537,429	1,517,030	24,130	

*Purposes — I — Irrigation, P — Power, M — Municipal, FW — Fish & Wildlife, FC & Flood Control

GROUND WATER

Springs were the most important source of fresh water for early settlers. With the development of modern drilling techniques, the relative importance of springs has diminished, and wells have become the dominant means of utilizing this valuable resource. Depths to ground water are governed by the geologic structure and the amount of erosion and deposition at the drilling site.

The most widespread uses of ground water are for domestic and stock watering purposes. Those persons who rely on surface water live primarily in the cities and larger towns, while the population in rural areas and in most of the smaller towns almost exclusively utilizes ground water for domestic consumption. Of the 695,000 people in the state in 1970, about half used only ground water in their homes.

Because of the significant role of ground water, its availability and purity have been the subject of numerous studies. The Ground-Water Studies Map on page 53 shows the areas of the state in which such studies have been completed.

ARTESIAN WELL

Quantity

An aquifer is a water-bearing geological formation. There are basically two types of ground-water aquifers: the consolidated rock aquifer, in which the gravels, sands, or rock are cemented together, and the water lies within the consolidated material; and the unconsolidated aquifer, such as streambed alluvium, in which the water lies within or flows through loose gravel and sands.

The Extensive Aquifers Map on page 55 shows the principal ground-water aquifers in Montana. Geologic conditions differ widely from one region of the state to the next, and aquifers of primary importance on one side of the divide may be insignificant on the other. Because of this, the following discussion of principal aquifers is organized by region. Alluvium, an important source of ground water throughout the state, is included as a separate category.

East. The consolidated rock aquifers of primary significance exist in the stratified formations underlying most of the area east of the Rockies. There are many water-bearing formations in eastern Montana, but, owing to the complexity of the area's geology, not all the aquifers are present in any one area.

The Great Plains province is predominantly underlain by the Fort Union geologic formation made up of stratified sandstones, shale, and coal beds. The sandstones and coal beds are often important aquifers for small yields of less than 30 gallons per minute (gpm). Beneath the Fort Union Formation lie thousands of feet of older stratified rock, containing as principal aquifers the Hell Creek-Fox Hills, important because of the artesian conditions present, and the much deeper Muddy, Dakota and Kootenai sandstones. Along the western edge of the plains area, the Judith River Formation is a useful source of ground water.

Central. The ground-water situation in the central portion of the state is more complex due to the greatly eroded geologic structures in which many ancient, stratified formations are exposed at the surface. Porous and permeable rocks are thus favorably situated to receive surface water recharge, and some streams actually disappear beneath the surface at locations where such aquifers are exposed.

Aquifers such as the Judith River, Eagle-Virgelle, First Cat Creek-Dakota, and Third Cat Creek-Kootenai are recharged along their outcrops in upturned flanks of the mountains. These water-bearing formations frequently yield water under artesian conditions and are the source of large springs. High water-table conditions are characteristic of these aquifers and also of the gravel benches found adjacent to the larger isolated mountain ranges, particularly the Big Snowys. These gravel benches may, however, be well drained due to their relatively higher topography, but in many localities small to moderate amounts of ground water can be obtained.

The Madison limestone, a much deeper formation, has a potential for producing water in large quantities in both eastern and central Montana. It varies in depth throughout Montana but outcrops and is not as deeply buried in the central region. The water is normally under pressure — so much pressure, in fact, that special precautions must be taken to prevent damage to equipment releasing the water. Because the withdrawal of massive amounts of water from this aquifer has been proposed for use in the shipment of coal by slurry pipeline (Rahn 1975), the future of the Madison limestone is currently controversial. There is concern that continued large withdrawals will result in the drawdown of other wells and springs in this aquifer. Madison water varies in quality, but in some places contains only 450-550 parts per million (ppm) of dissolved solids (Rahn 1975); at other sites, chemical quality may limit its uses for irrigation and some industrial production.

West. Western Montana has numerous intermontane valleys containing rock material eroded from the nearby mountains. The mountains themselves, too impervious to hold ground water, allow a large amount of runoff to the valleys. The sediments in many of these valleys are often several thousand feet thick, porous, and permeable, forming vast ground-water reservoirs.

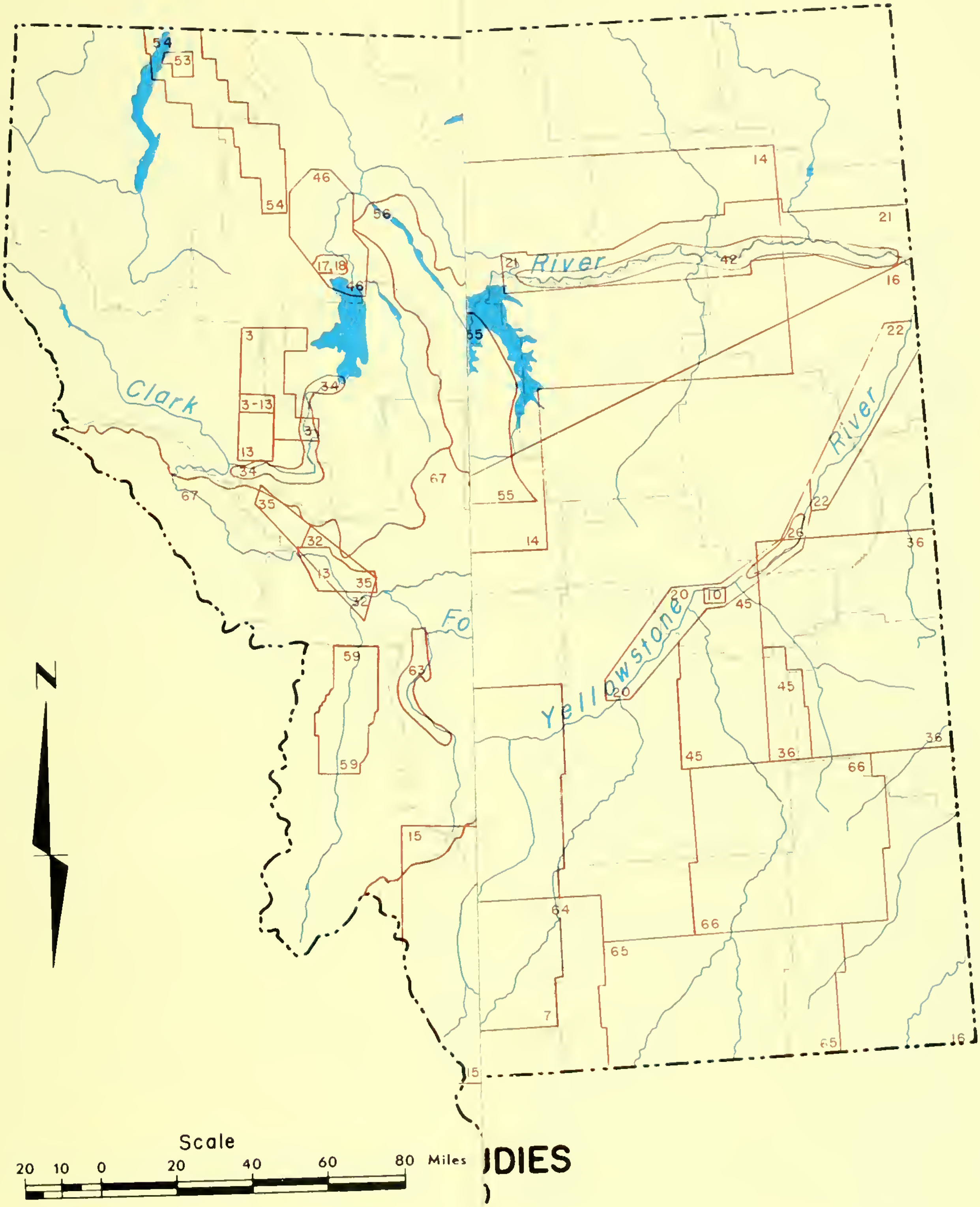
Alluvium. The alluvium deposited by rivers throughout the state is a valuable source of large quantities of ground water. These deposits of gravel, sand, silt, and clay are of recent geological age and therefore are not cemented or consolidated. The higher fill deposits, which form rolling hills in the valleys, are less porous and permeable than the alluvium below. The alluvial gravels near the streams are capable of yielding sufficient water for most uses, while the higher deposits produce lesser quantities.

Extensive alluvium deposits are found along the Yellowstone and Milk Rivers east of the Rockies and along many rivers in western Montana. Small deposits of alluvium are found along and beneath almost all ephemeral and perennial streams and generally yield supplies of water adequate for domestic use.

The alluvium in much of the northern half of Montana is complicated by the effects of glaciation. The vast deposits left by glaciers in the valleys and on the plains are less permeable than alluvium and in some areas cause the valley fill to be devoid of producible water. This is especially true in the valleys of the Kootenai and Flathead Rivers in northeastern Montana. Some glacial deposits, however, do yield small supplies of ground water.

Quality

Ground water in western Montana, which generally contains less than 1,000 ppm of total dissolved solids (TDS), is of higher quality than that in eastern Montana (see Ground-Water Quality Map on page 57). The subject of ground-water quality is further discussed in **The Framework Report, Volume Two.**



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UDIES

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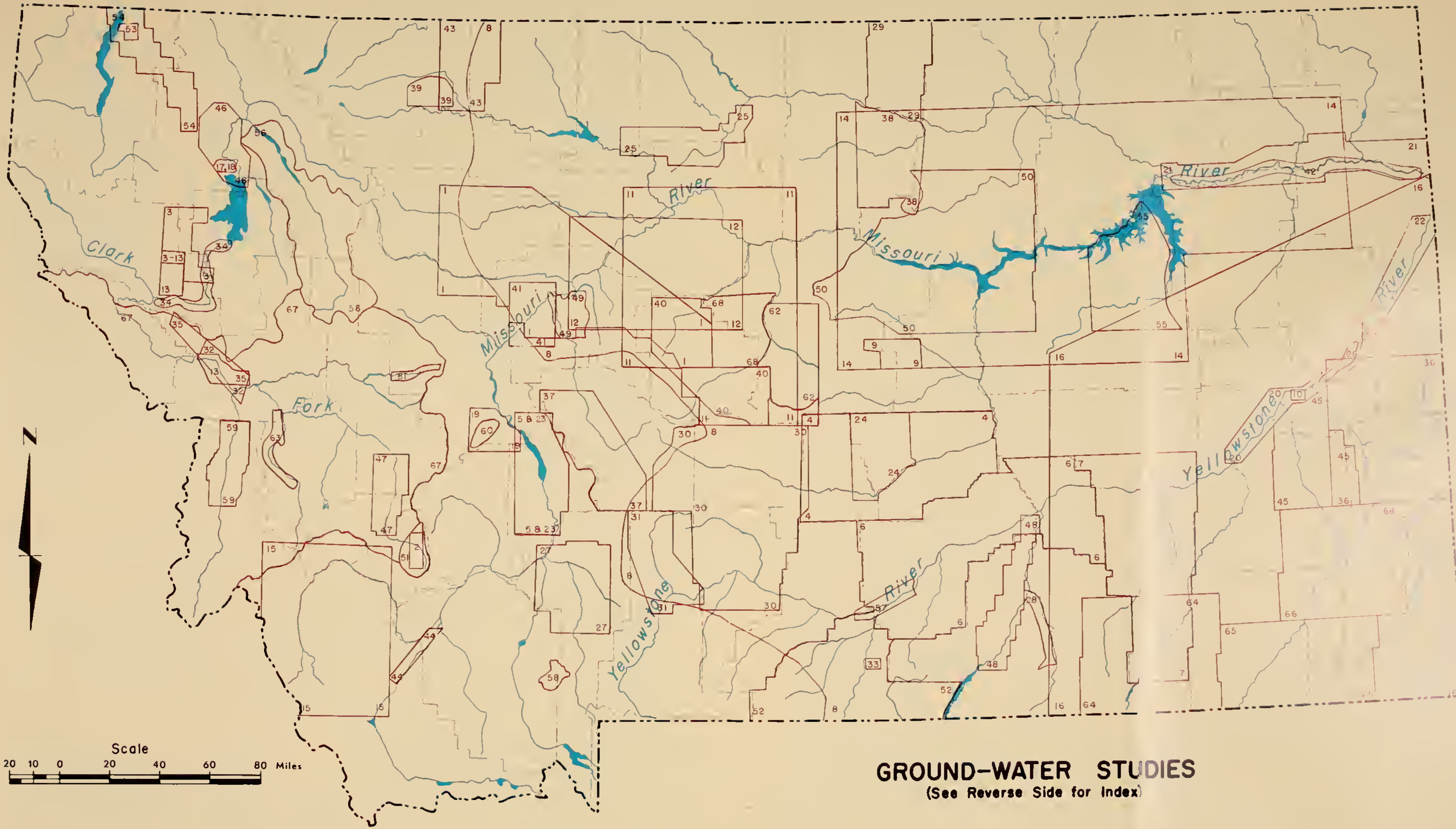
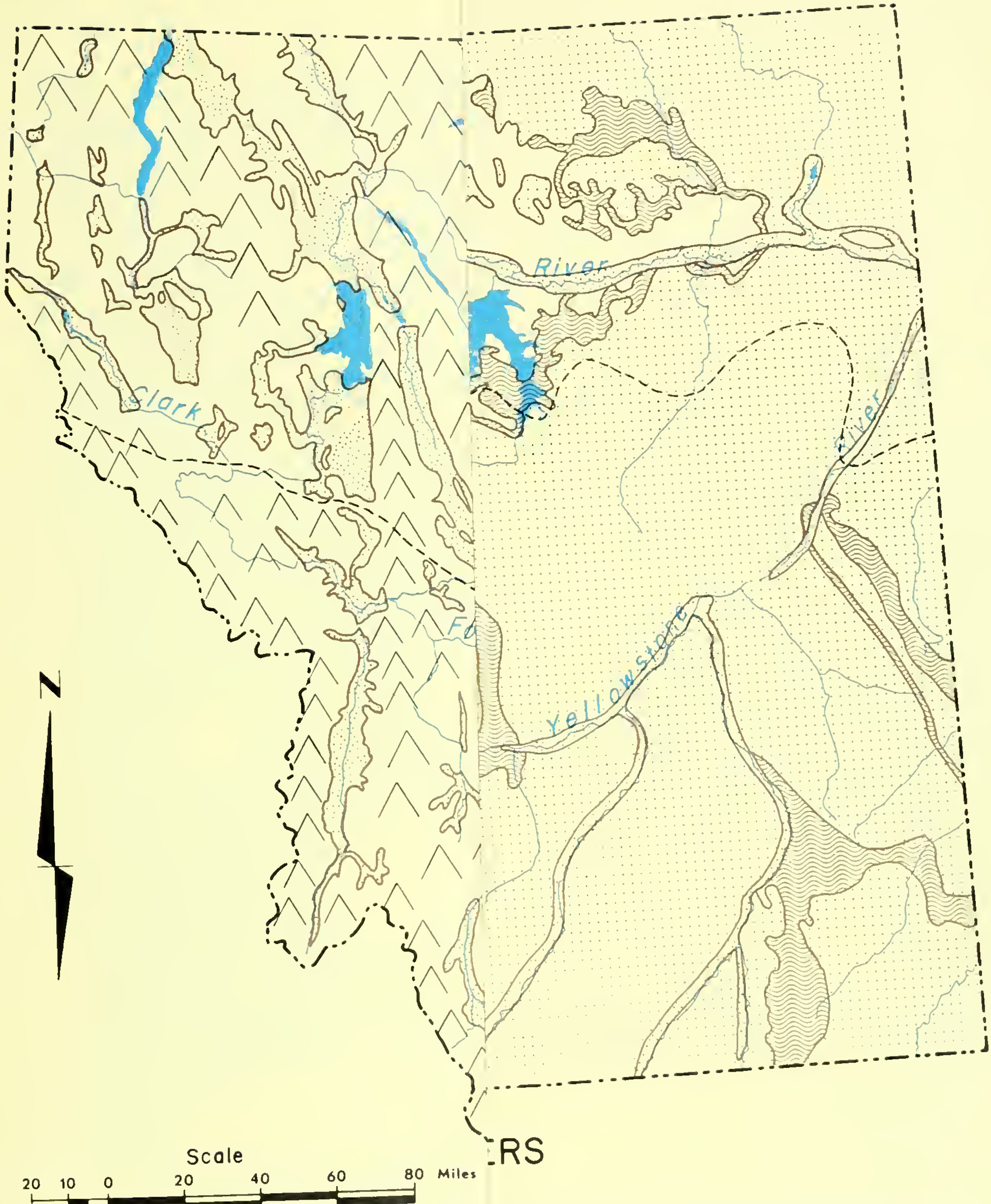


GROUND-WATER STUDIES
(See Reverse Side for Index)



RS

KOOTENAI – Sandstone beds near surface capable of yields up to 300 gpm

Generally characterized by less extensive ground-water aquifers

Southernmost line of Glaciation (North of this line the reliability of obtaining ground water from alluvial deposits is diminished)

Mountainous areas

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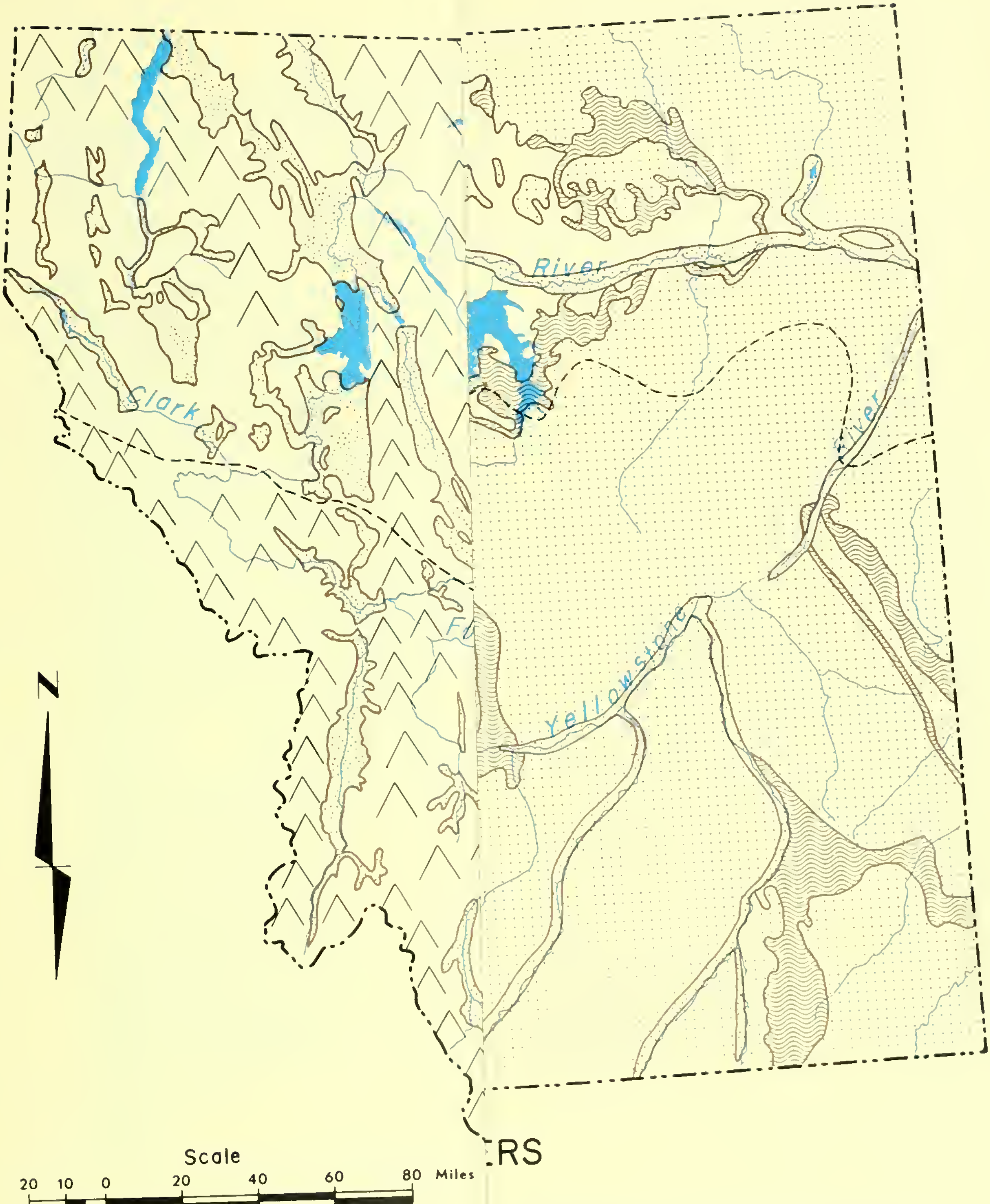
EXPLANATION OF ABBREVIATIONS

USGS — United States Geological Survey
MBMG — Montana Bureau of Mines and Geology
MDNRC — Montana Department of Natural Resources and Conservation
WSP — Water Supply Paper
M — Memoir
B — Bulletin
MC — Miscellaneous Contribution
Circ. — Circular
IC — Information Circular
SP — Special Publication
HA — Hydrologic Atlas
WRI — Water-Resources Investigations



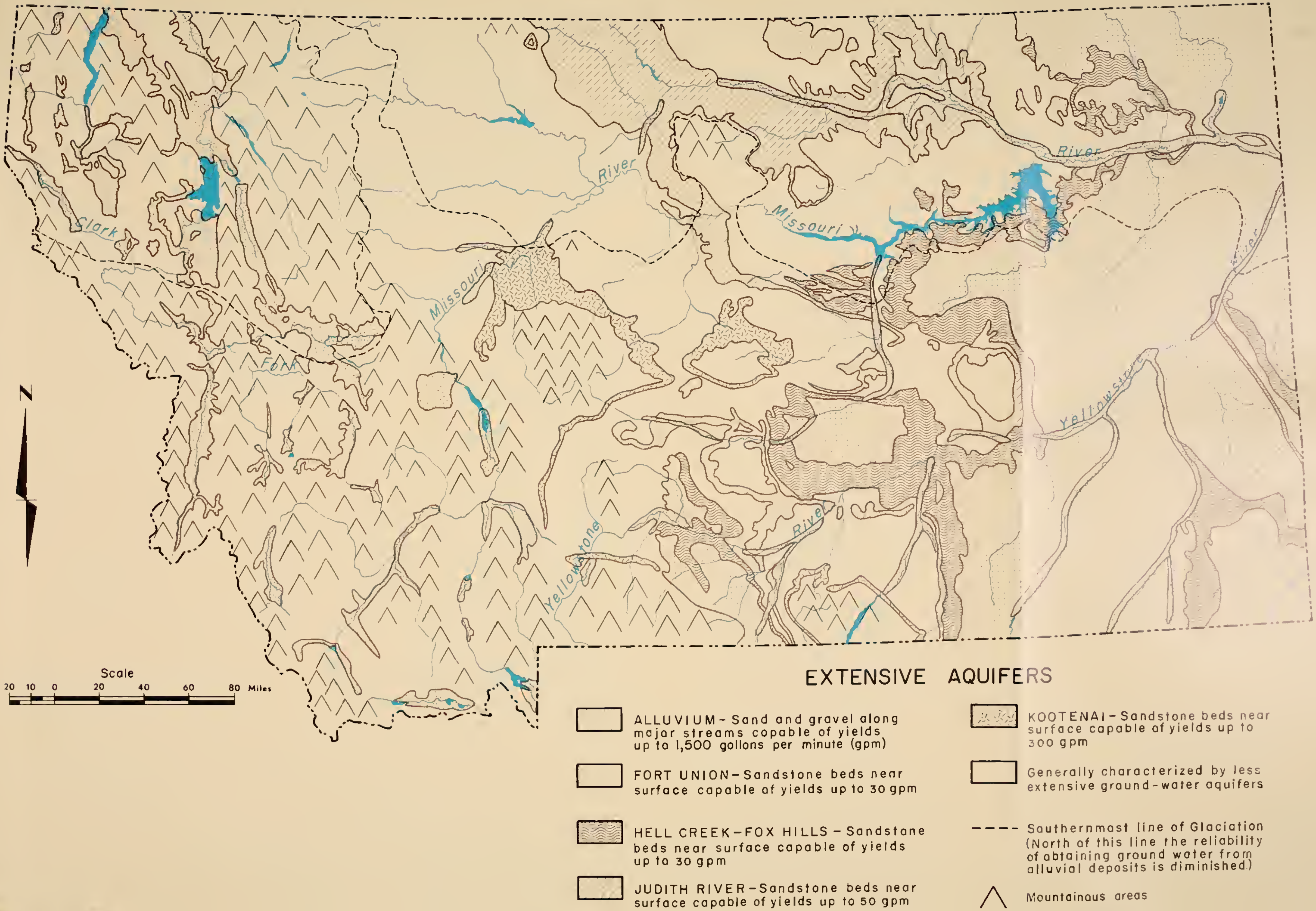
ERS

KOOTENAI - Sandstone beds near surface capable of yields up to 300 gpm

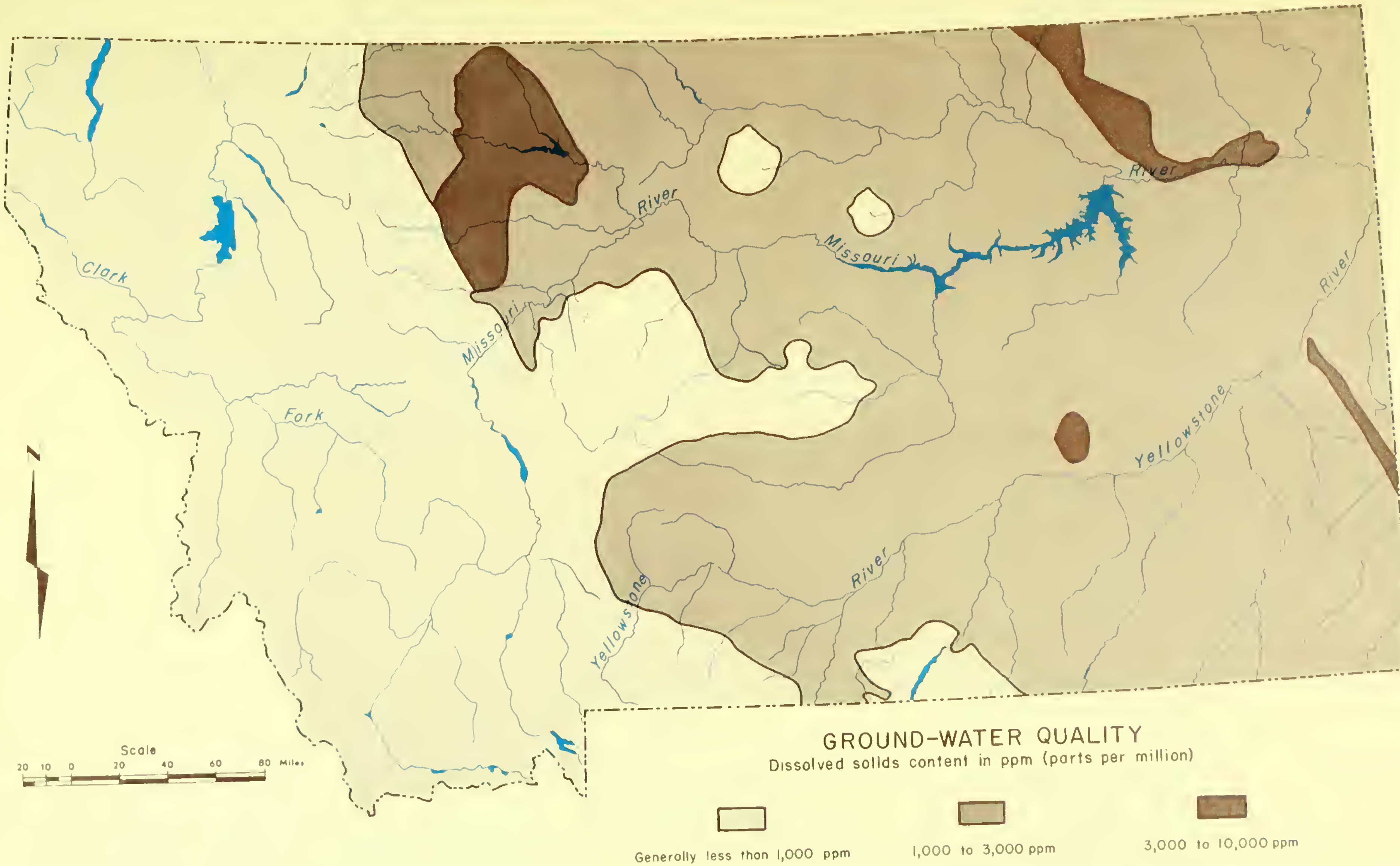
Generally characterized by less extensive ground-water aquifers

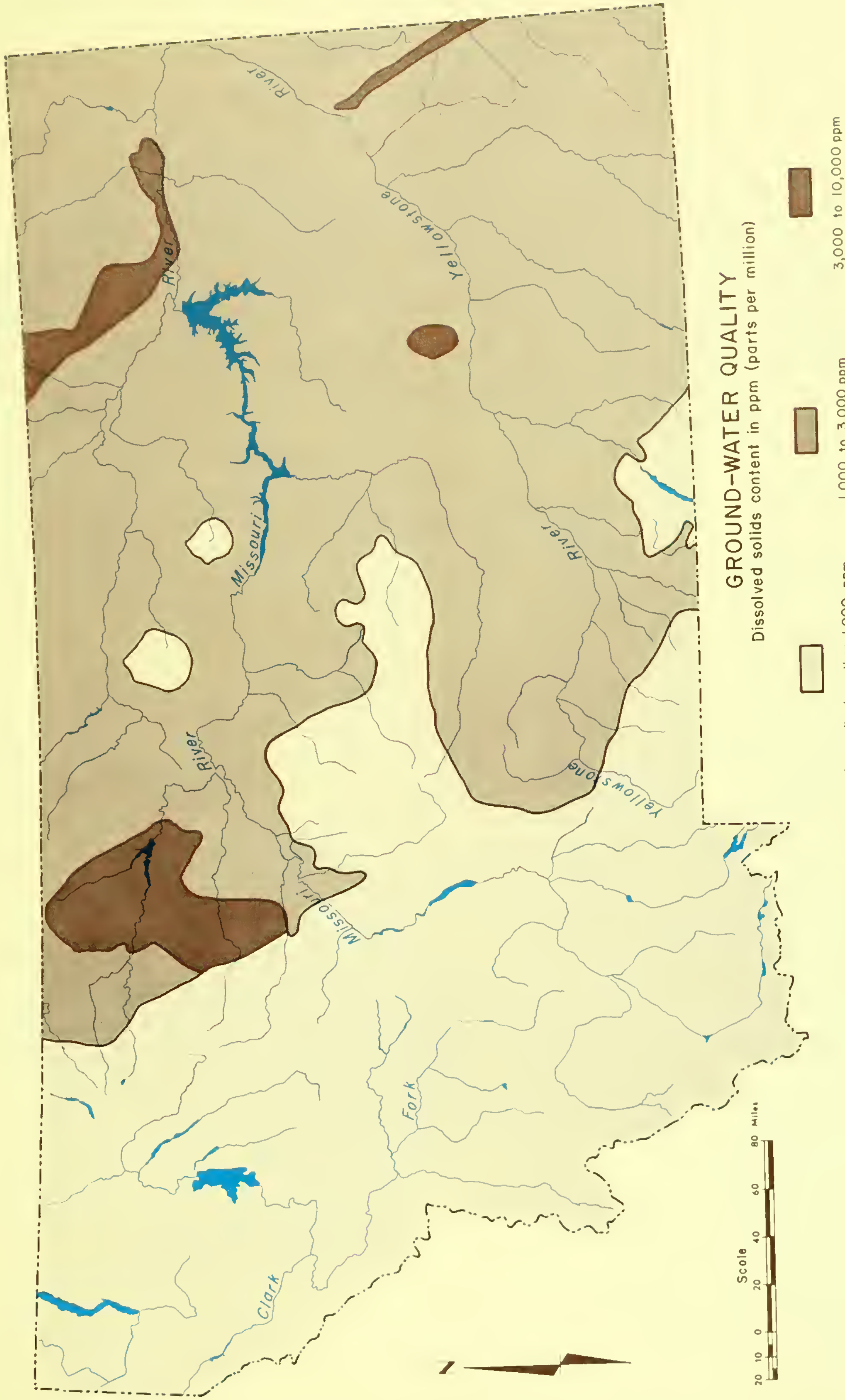
Southernmost line of Glaciation (North of this line the reliability of obtaining ground water from alluvial deposits is diminished)

Mountainous areas



Clark
Fork
Missouri
River
Missouri
River
Yellowstone
River
Yellowstone
River
N
Scale
20 10 0 20 40 60 80 Miles
EXTENSIVE AQUIFERS
ALLUVIUM – Sand and gravel along major streams capable of yields up to 1,500 gallons per minute (gpm)
FORT UNION – Sandstone beds near surface capable of yields up to 30 gpm
HELL CREEK – FOX HILLS – Sandstone beds near surface capable of yields up to 30 gpm
JUDITH RIVER – Sandstone beds near surface capable of yields up to 50 gpm
KOOTENAI – Sandstone beds near surface capable of yields up to 300 gpm
Generally characterized by less extensive ground-water aquifers
Southernmost line of Glaciation (North of this line the reliability of obtaining ground water from alluvial deposits is diminished.)
Mountainous areas


Clark
Fork
Missouri
River
Missouri
River
Yellowstone
Yellowstone
River
River
Scale
20 10 0 20 40 60 80 Miles
GROUND-WATER QUALITY
Dissolved solids content in ppm (parts per million)
Generally less than 1,000 ppm
1,000 to 3,000 ppm
3,000 to 10,000 ppm


GROUND-WATER QUALITY
Dissolved solids content in ppm (parts per million)
Generally less than 1,000 ppm
1,000 to 3,000 ppm
3,000 to 10,000 ppm
Scale
20 10 0 20 40 60 80 Miles
Missouri River
Yellowstone River
Clark Fork

LAND RESOURCES

Montana, the nation's fourth largest state, averages 500 miles in length and 275 miles in width. The state contains 94,168,000 acres (147,138 square miles), of which 900,000 acres (1,400 square miles) is water area.

LAND AREA AND OWNERSHIP

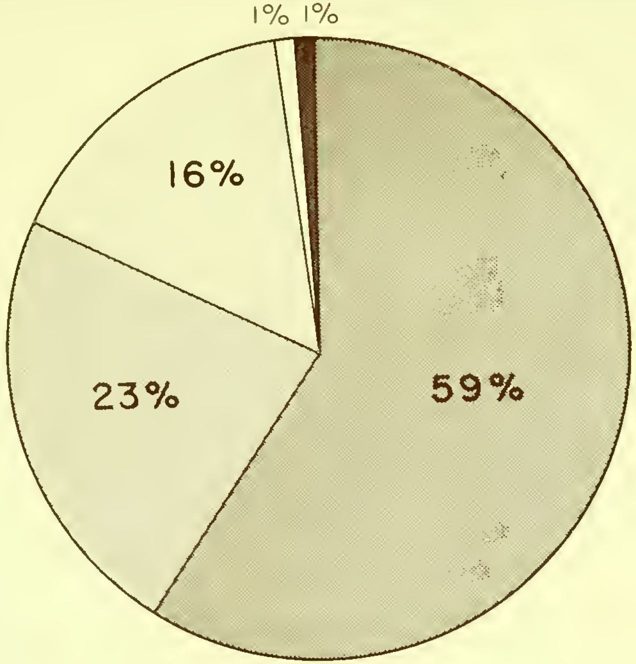
Table 11 catalogs land area and ownership in Montana, which are also illustrated in Figure 1.

The federal government owns or administers 27,600,000 acres in the state, 29.6 per cent of the total land area. The Forest Service of the U.S. Department of Agriculture administers over 16 million acres of forested public land, and the Bureau of Land Management of the U.S. Department of the Interior administers over 8 million acres of rangeland. The National Park Service of the U.S. Department of the Interior, the only other major land administrator, is responsible for over 1 million acres of Glacier and Yellowstone National Parks. Other federal agencies manage the remaining federal land in Montana.

TABLE 11

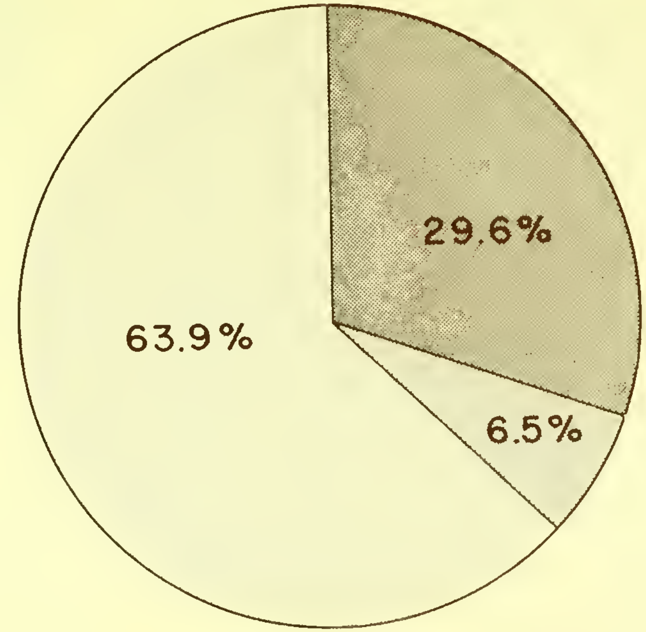
LAND AREA AND OWNERSHIP

Administrator	Acres	Percentage of Total Land Area
Federal Government	27,607,034	29.6
Dept. of Agriculture	16,710,126	17.9
Dept. of the Interior	10,295,070	11.0
Dept. of Defense	601,203	.6
Federal Aviation Agency	275	
General Services Admin.	154	
Veterans Administration	149	
Dept. of Health, Ed., & Welfare	33	.1
Dept. of Justice	12	
Post Office Department	6	
Treasury Department	5	
State Government	6,097,910	6.5
Dept. of State Lands	5,275,892	5.7
Forestry Division, DNRC	489,189	.5
Dept. of Fish and Game	130,000	.1
Dept. of Highways	81,000	.1
University Units	47,733	.05
Institutions	38,444	.05
Water Resources Division, DNRC	24,980	
Other	640	
Private Ownership	59,566,096	63.9
Indian Reservations	6,420,000	6.9
Railroads	1,290,198	1.0
Other Private Land	51,855,898	56.0
Total Land Area	93,271,040	
Total Water Area	897,280	
Total Area of State	94,168,320	



LAND USE

Pasture & Range	55,327,000	59%
Forest & Woodland	22,048,000	23%
Cropland	15,078,000	16%
Urban, Built up & Other	818,000	1%
Water Area	897,000	1%
Total Area	94,168,000	



LAND OWNERSHIP

Federal	27,607,000	29.6%
State	6,098,000	6.5%
Private	59,566,000	63.9%
Total	93,271,000	

USE AND OWNERSHIP
OF MONTANA'S LAND

FIGURE I

The State of Montana's agencies or institutions own or administer over 6 million acres of land, 6.5 per cent of the land area of the state. School trust lands alone, administered by the Department of State Lands, total over 5 million acres. State forest lands amount to just under one-half million acres and are administered by the Division of Forestry of the Department of Natural Resources and Conservation. The Water Resources Division, DNRC and other state agencies oversee the remaining one-third million acres of state land.

The remaining 63.9 per cent of the land in Montana (nearly 60 million acres) is privately owned. Of this, 6.4 million acres is Indian-owned reservation land.

LAND COVER AND USE

The predominant use of Montana's land resource is for pasture and range for livestock grazing. Even the vast forest and woodland resource is used in part for livestock grazing. Twenty-five per cent of the pasture and less than one per cent of the range are irrigated.

While rangeland dominates eastern Montana, woodland areas, primarily evergreen forests, dominate the western half of the state. In addition to the 16 and one-half million acres administered by the federal and state governments, five and one-half million acres are owned by private concerns, including large corporations. Much of our state's water originates as runoff from forested areas. Snowfall and precipitation are controlled to a great degree by the ground cover upon which they fall, and the forest cover perhaps best controls runoff and regulates the timely release of the water supply.

Fifteen million acres of cropland are in production in the state. Most, 12.5 million acres, is dryland, and the remainder is irrigated. Montana's major water use is irrigating these 2.5 million acres of cropland.

Urban, built up, and other land uses occupy less than one per cent of the land. Water areas also cover approximately one per cent.

FERTILE GALLATIN VALLEY PASTURELAND

CONCLUSION

Volume One has presented a general description of water planning and the water-related resource situation in Montana. Certainly much more could be said about the physical characteristics, hydrology, and land use of the state, but the intent of this volume is to introduce the reader to subjects which will be discussed in greater detail in **Volume Two**.

Various aspects of water resource — availability, use, problems, and opportunities — will be the subjects of **Volume Two**. The land resource will be discussed as it is related to the water resource, and population projections will present a picture of water use in the future.

Volume Three will not only discuss legal and institutional constraints and considerations, but will also draw conclusions and make recommendations based on the material in all three reports.

QUIET SPLENDOR OF SALMON LAKE

APPENDIX

STREAMFLOW HYDROGRAPHS

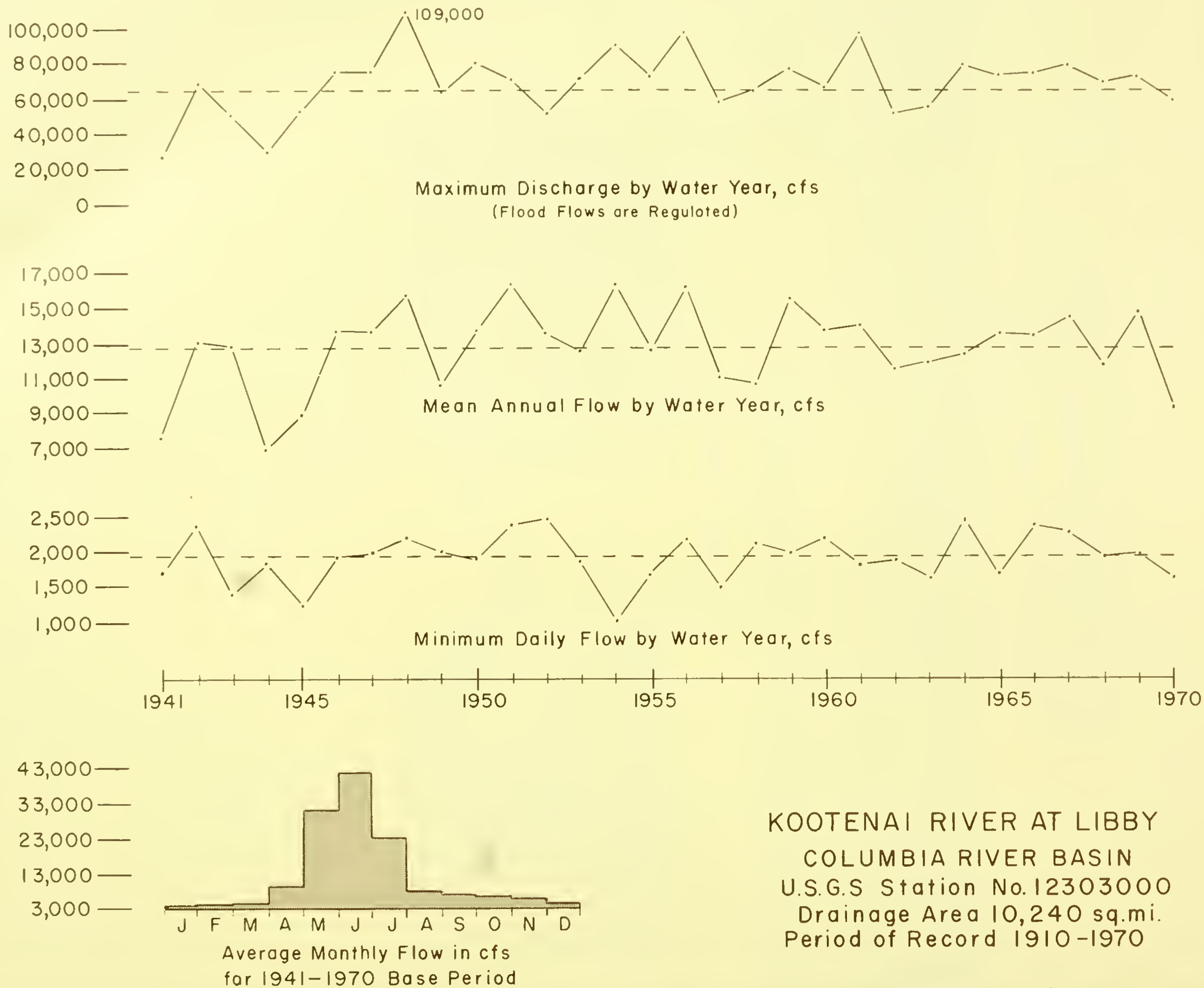
STREAMFLOW HYDROGRAPHS

Although the number of sites varies from year to year as some stations are discontinued and others added, in 1970 there were approximately 168 primary surface recording stations operating in Montana. Of this total, 84 were located in the Missouri River Basin, 36 in the Yellowstone River Basin, 31 in the Clark Fork Basin, 10 in the Kootenai River Basin, 6 in the St. Mary River Basin, and 1 in the Little Missouri River Basin. This total does not include stations for which the primary function is the operation of a given system (such as diversion stations for irrigation projects) or the collection of peak-flow and low-flow measurements.

Besides the various forms of streamflow data which are shown in the following hydrographs, supplemental data such as water quality and precipitation amount are collected at some stations.

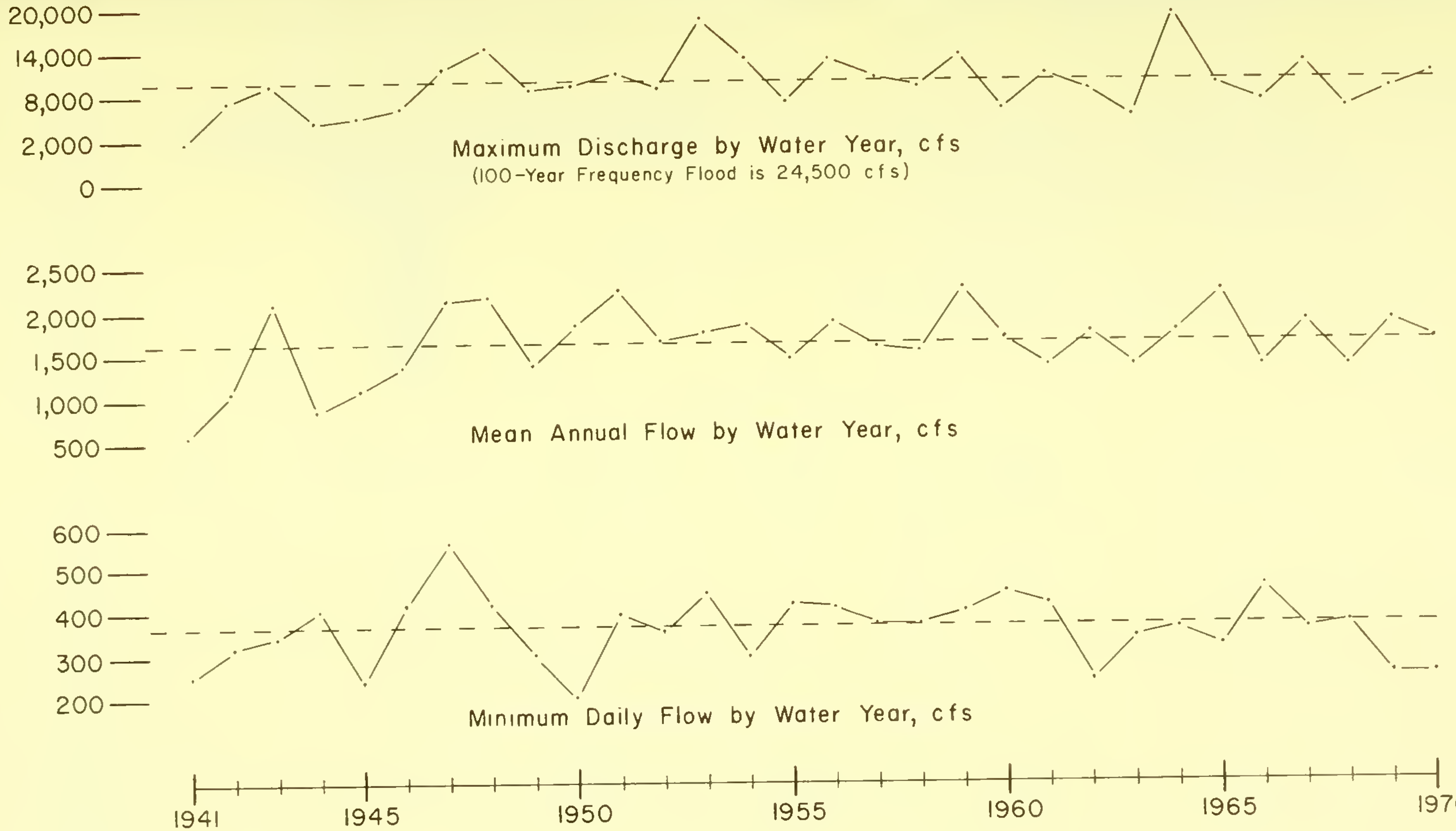
LIST OF HYDROGRAPHS

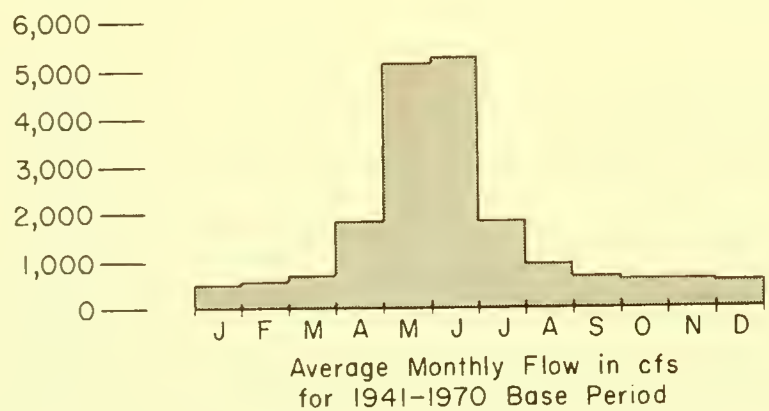
A- 1. Kootenai River at Libby
A- 2. Blackfoot River near Bonner
A- 3. Clark Fork above Missoula
A- 4. Bitterroot River at Florence
A- 5. Flathead River at Columbia Falls
A- 6. Flathead River near Polson
A- 7. Clark Fork near Plains
A- 8. Beaverhead River near Twin Bridges
A- 9. Jefferson River at Sappington
A-10. Madison River near McAllister
A-11. Gallatin River at Logan
A-12. Missouri River at Toston
A-13. Sun River near Vaughn
A-14. Marias River near Loma
A-15. Teton River near Dutton
A-16. Missouri River near Landusky
A-17. Musselshell River at Mosby
A-18. Milk River at Nashua
A-19. Missouri River near Culbertson
A-20. Yellowstone River near Livingston
A-21. Clarks Fork Yellowstone at Edgar
A-22. Bighorn River at Bighorn
A-23. Tongue River at Miles City
A-24. Yellowstone River at Miles City
A-25. Powder River near Locate
A-26. Yellowstone River near Sidney



KOOTENAI RIVER AT LIBBY
COLUMBIA RIVER BASIN
U.S.G.S Station No.12303000
Drainage Area 10,240 sq.mi.
Period of Record 1910–1970

FIGURE A-1

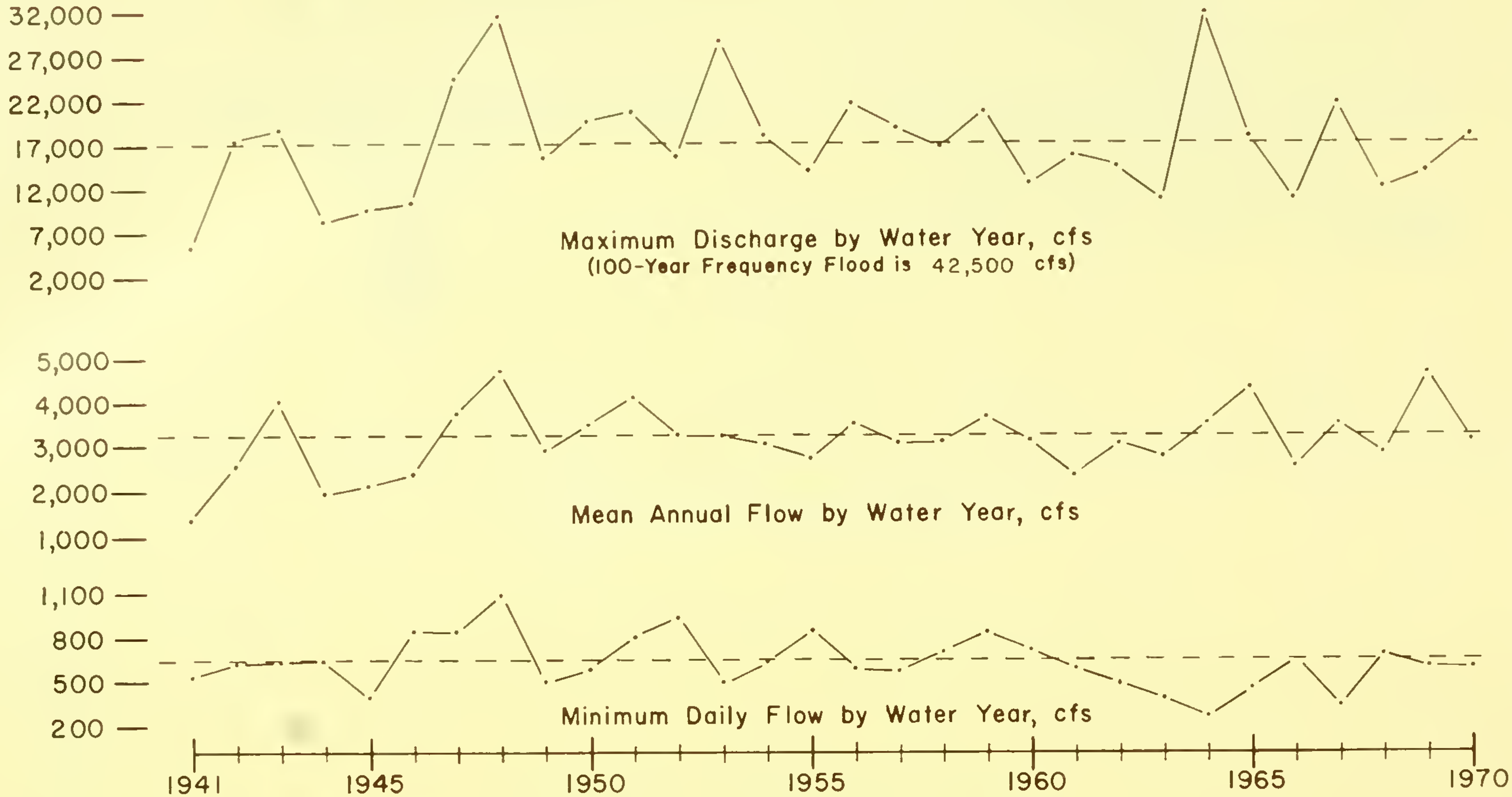


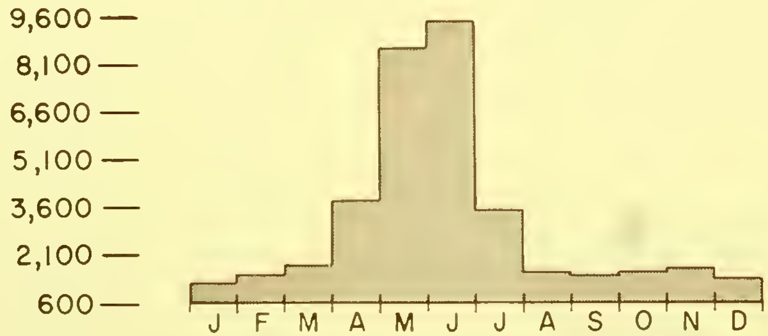


BLACKFOOT RIVER NEAR BONNER

COLUMBIA RIVER BASIN
U. S. G. S. Station No. 12340000
Drainage Area 2290 sq. mi.
Period of Record 1899-1901; 1903-1904
1939-1970

FIGURE A-2



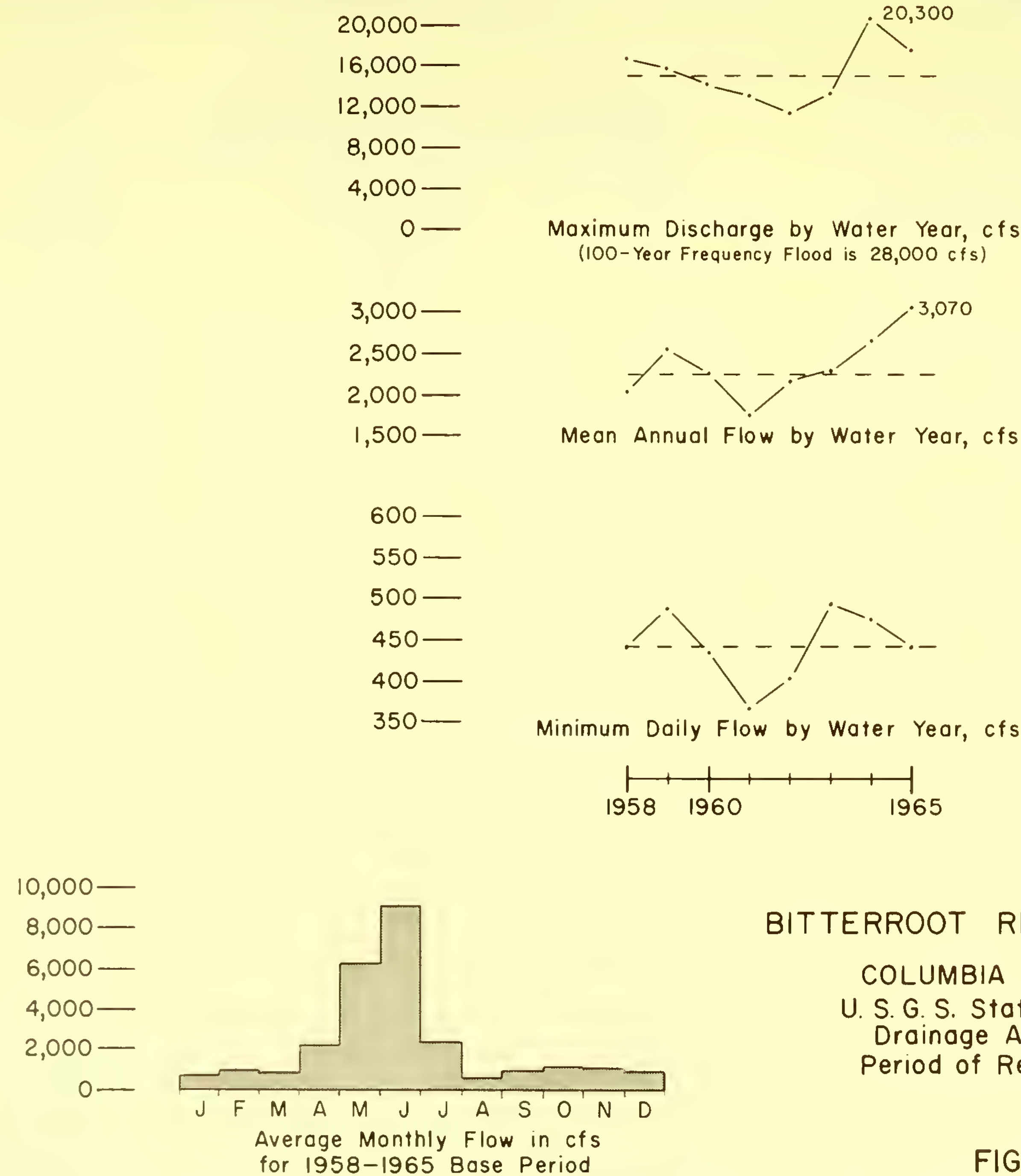


Average Monthly Flow in cfs
for 1941-1970 Base Period

CLARK FORK ABOVE MISSOULA

COLUMBIA RIVER BASIN
U. S. G. S. Station No. 12340500
Drainage Area 5,999 sq. mi.
Period of Record 1929-1970

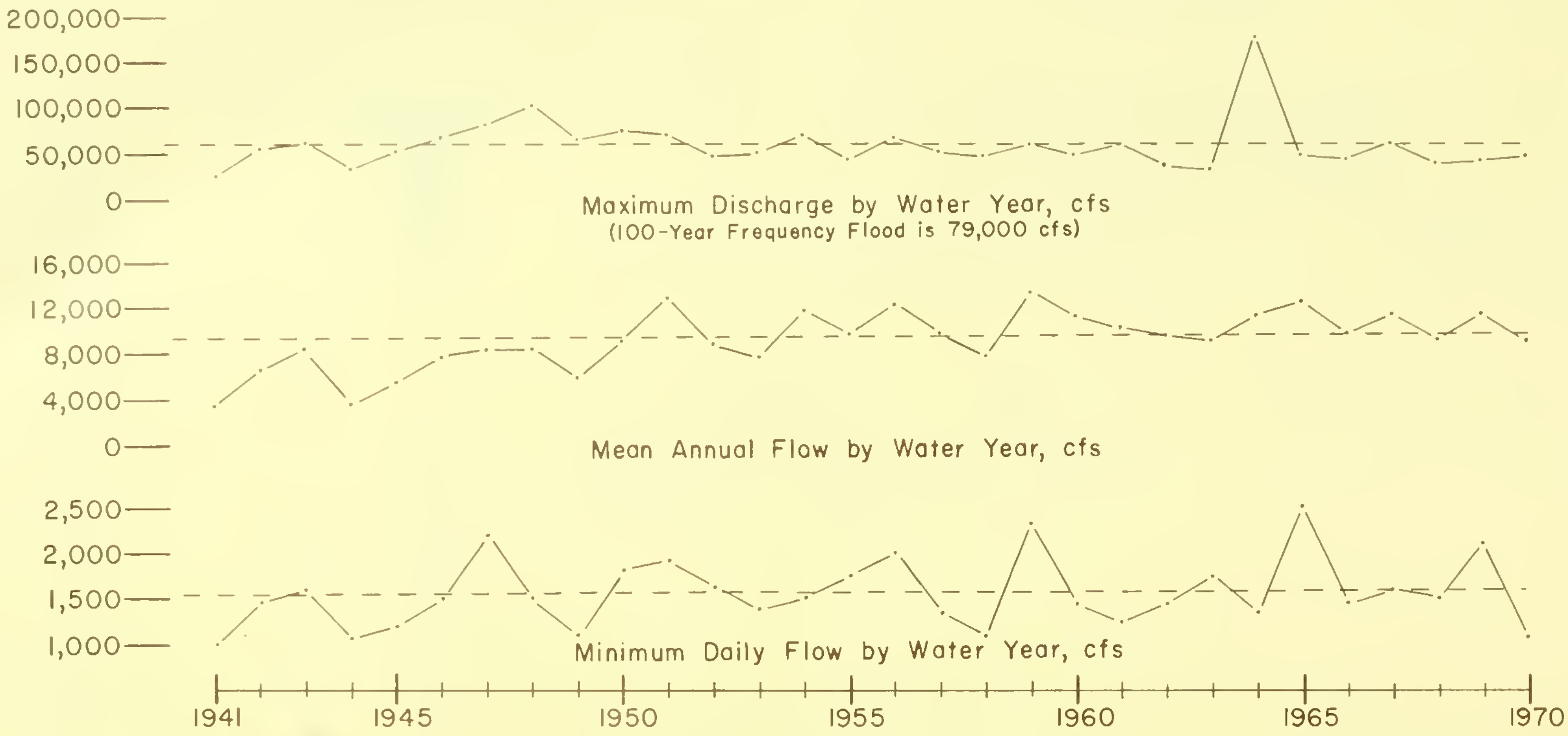
FIGURE A-3

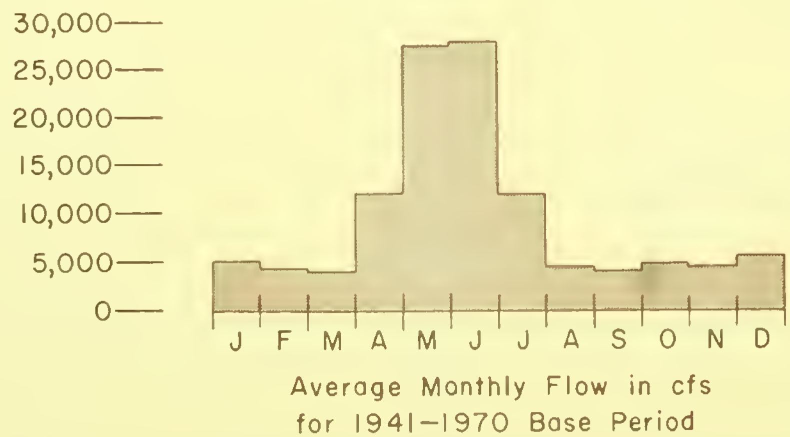


BITTERROOT RIVER AT FLORENCE

COLUMBIA RIVER BASIN
U. S. G. S. Station No. 12351200
Drainage Area 2354 sq. mi.
Period of Record 1958—1965

FIGURE A-4

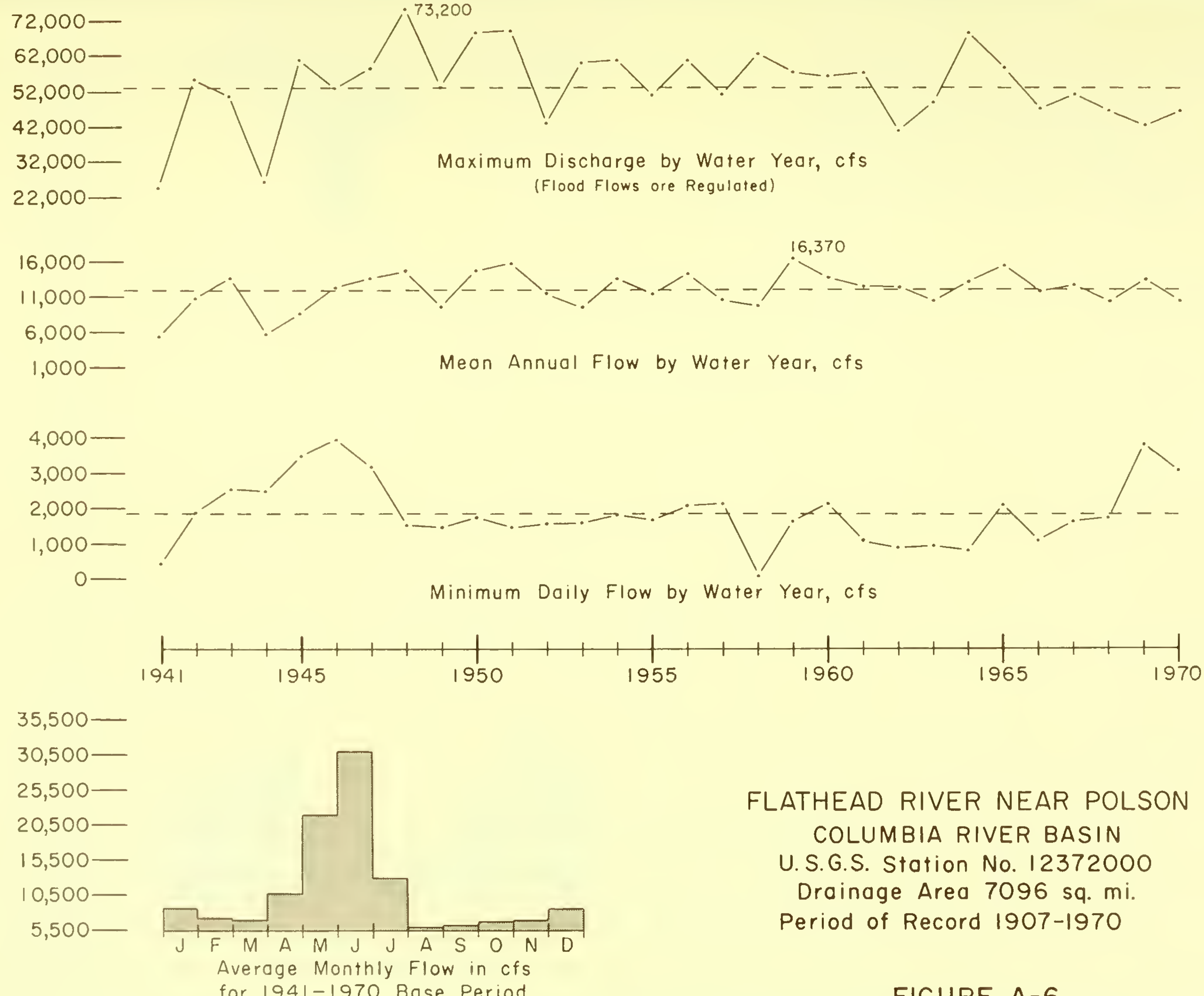




FLATHEAD RIVER AT COLUMBIA FALLS

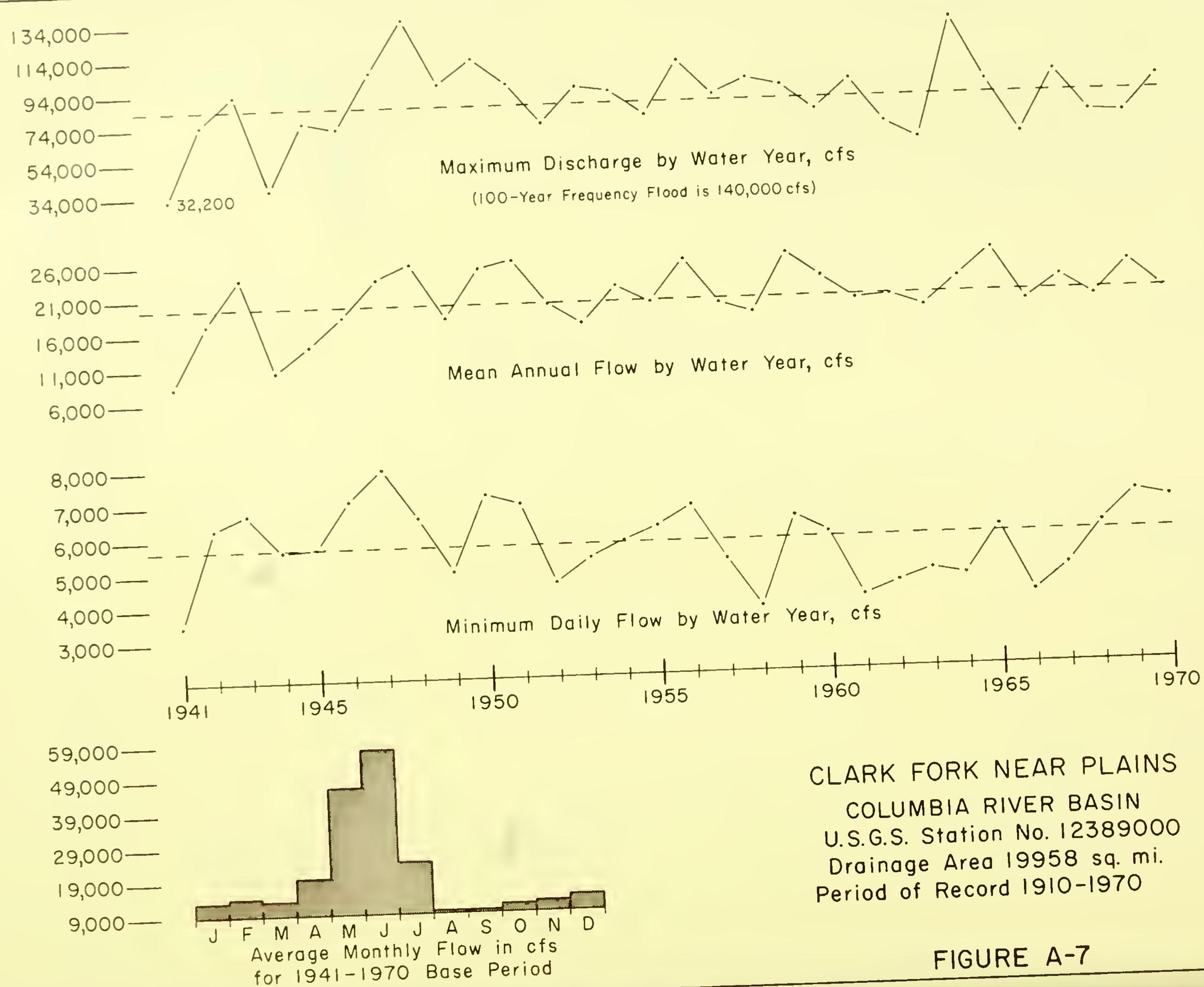
COLUMBIA RIVER BASIN
U. S. G. S. Station No. 12363000
Drainage Area 4,464 sq. mi.
Period of Record 1922–1923
1928–1970

FIGURE A-5



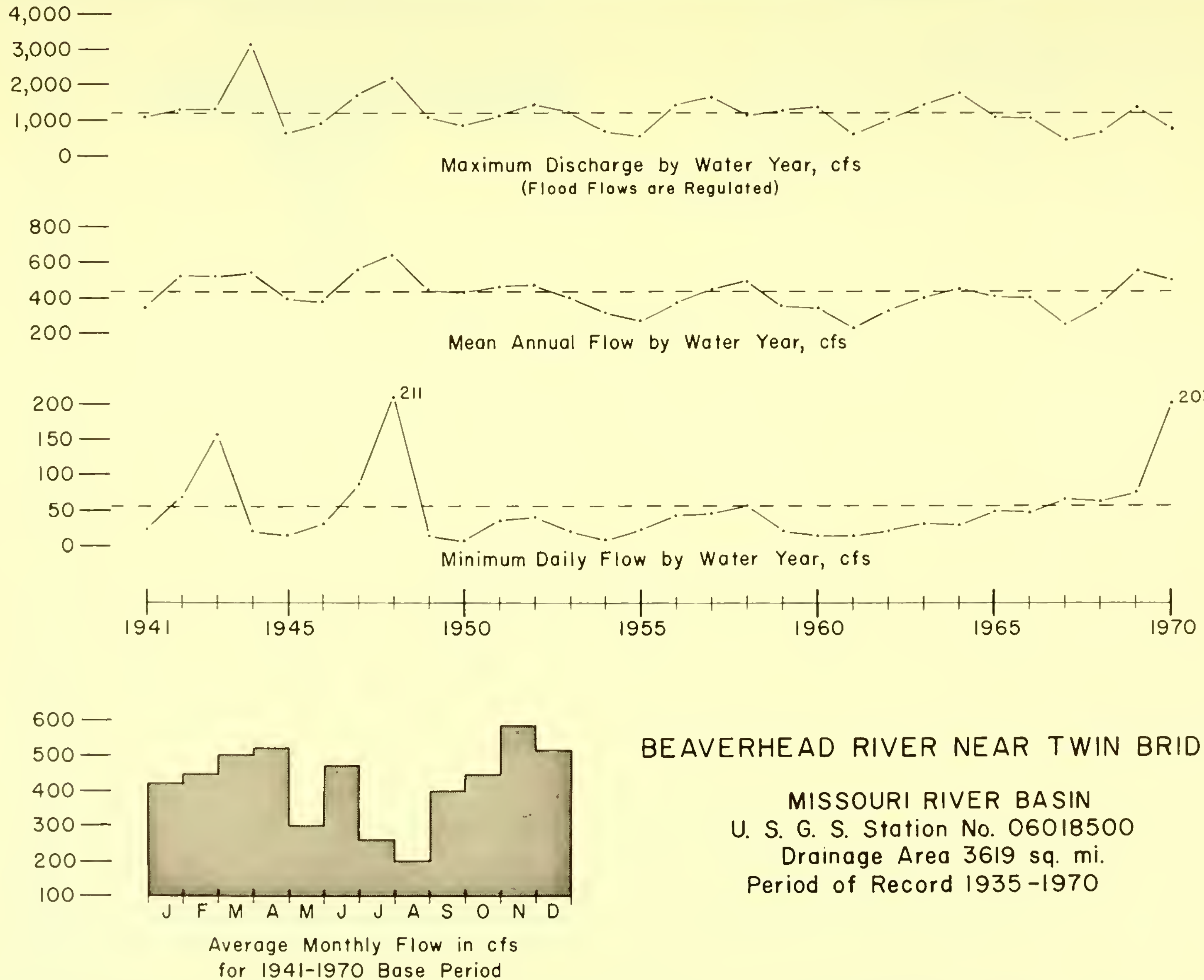
FLATHEAD RIVER NEAR POLSON
COLUMBIA RIVER BASIN
U.S.G.S. Station No. 12372000
Drainage Area 7096 sq. mi.
Period of Record 1907-1970

FIGURE A-6



CLARK FORK NEAR PLAINS
COLUMBIA RIVER BASIN
U.S.G.S. Station No. 12389000
Drainage Area 19958 sq. mi.
Period of Record 1910-1970

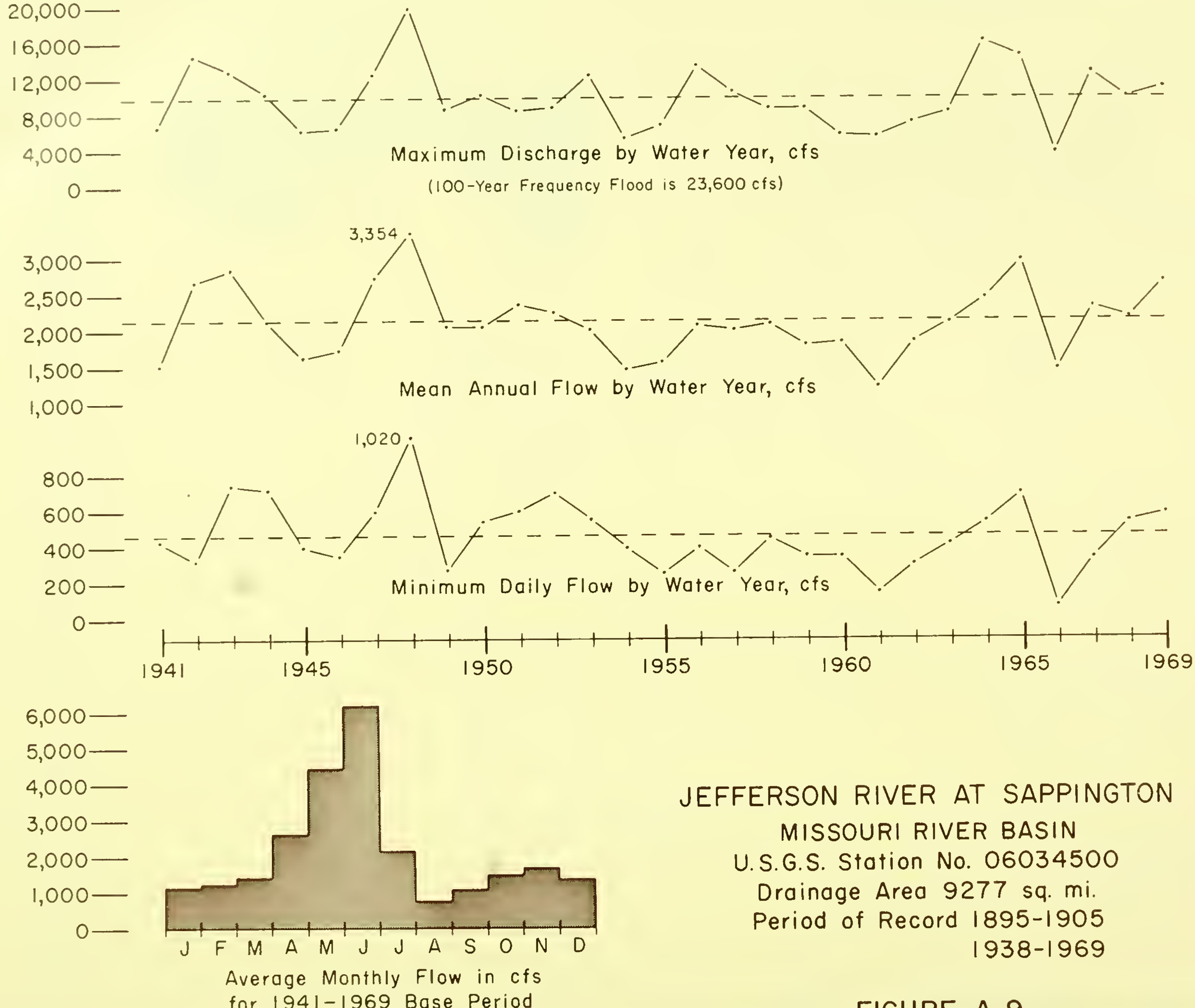
FIGURE A-7



BEAVERHEAD RIVER NEAR TWIN BRIDGES

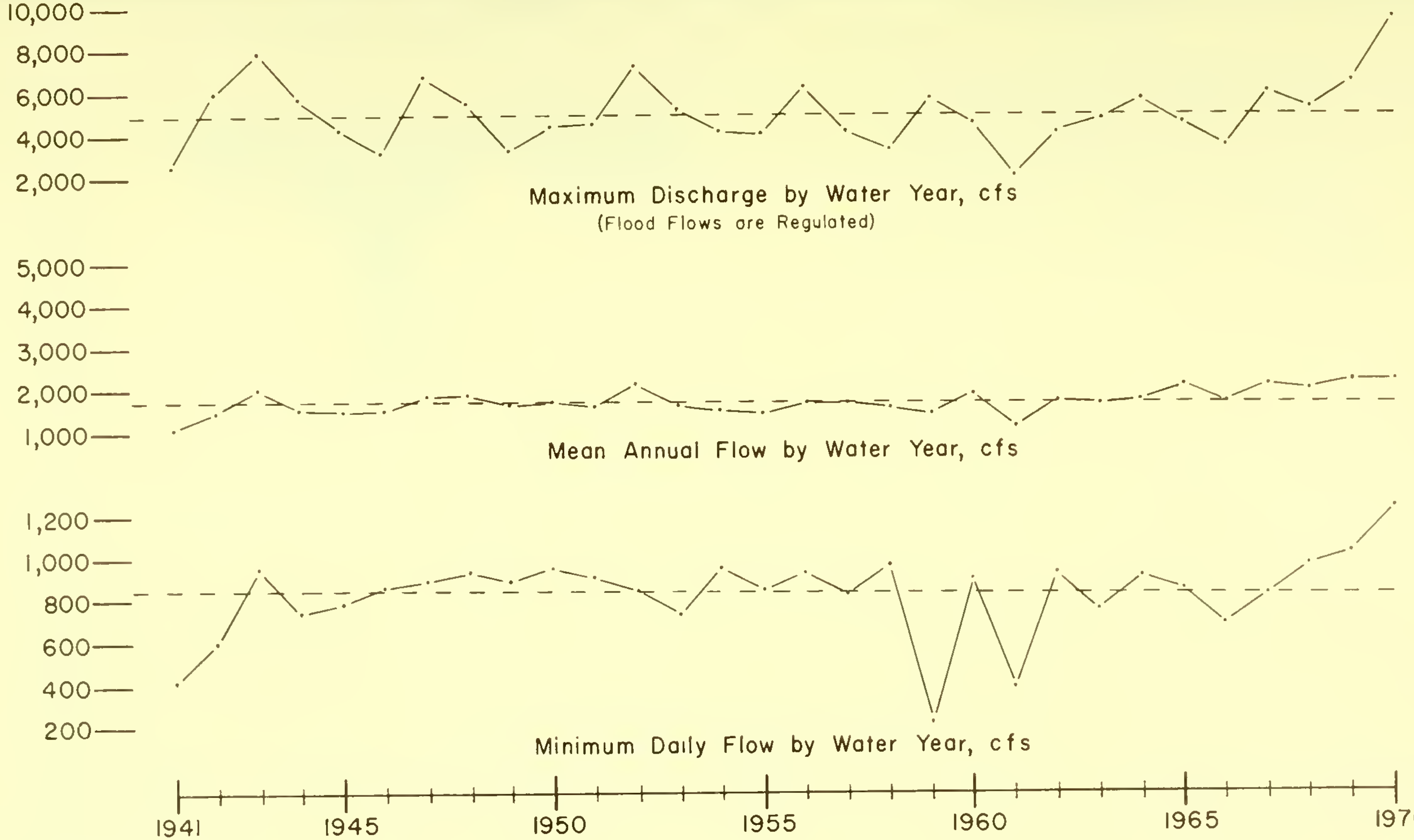
MISSOURI RIVER BASIN
U. S. G. S. Station No. 06018500
Drainage Area 3619 sq. mi.
Period of Record 1935-1970

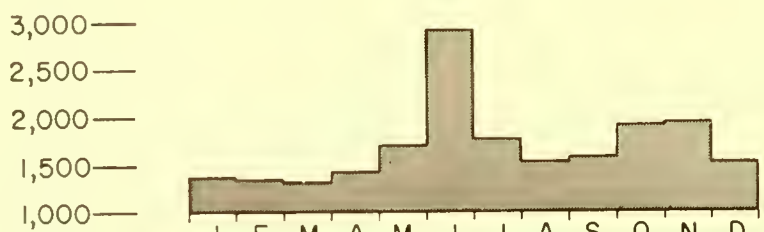
FIGURE A-8



JEFFERSON RIVER AT SAPPINGTON
MISSOURI RIVER BASIN
U.S.G.S. Station No. 06034500
Drainage Area 9277 sq. mi.
Period of Record 1895-1905
1938-1969

FIGURE A-9



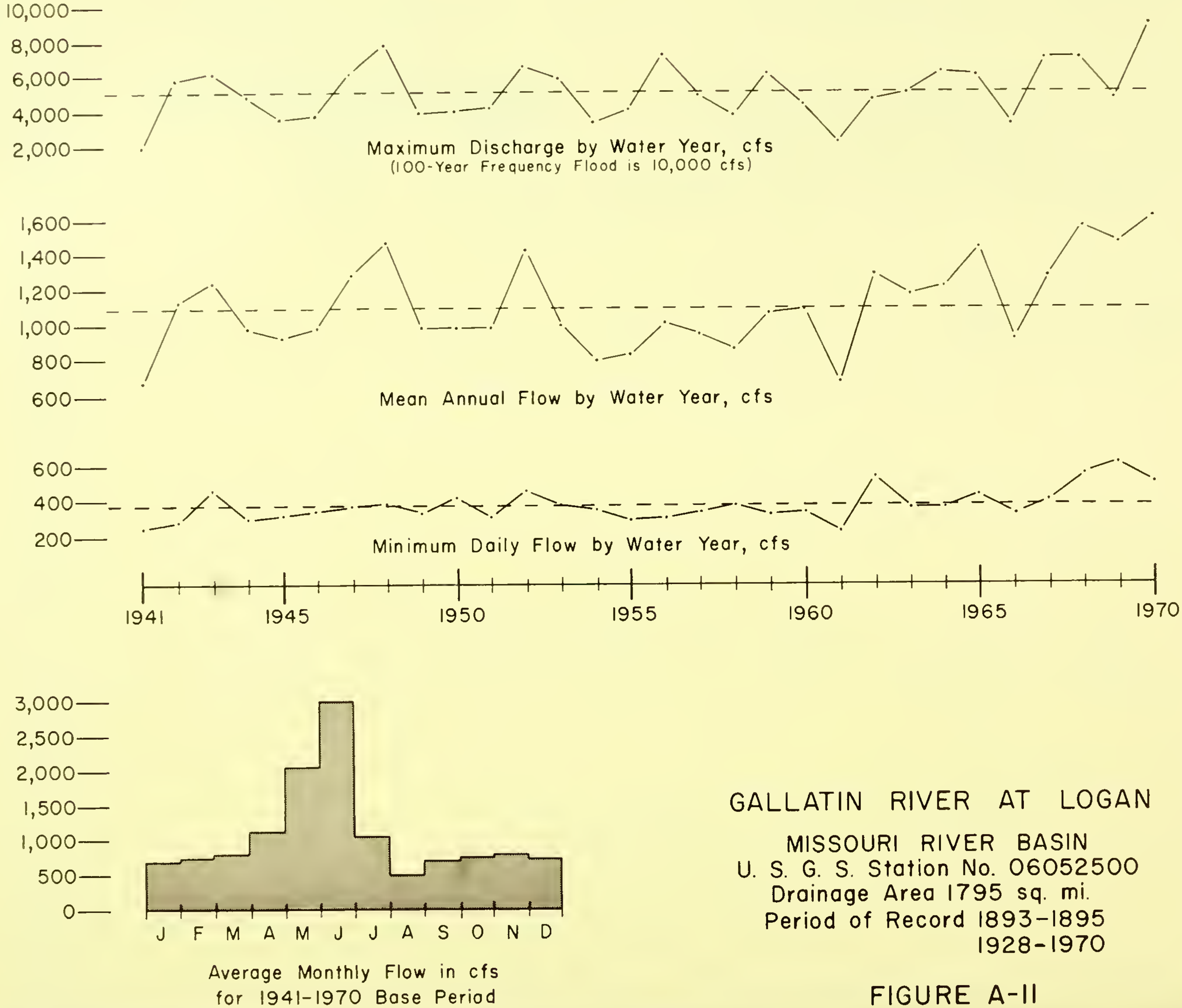


Average Monthly Flow in cfs
for 1941-1970 Base Period

MADISON RIVER NEAR McALLISTER

MISSOURI RIVER BASIN
U. S. G. S. Station No. 06041000
Drainage Area 2186 sq. mi.
Period of Record 1901-1970

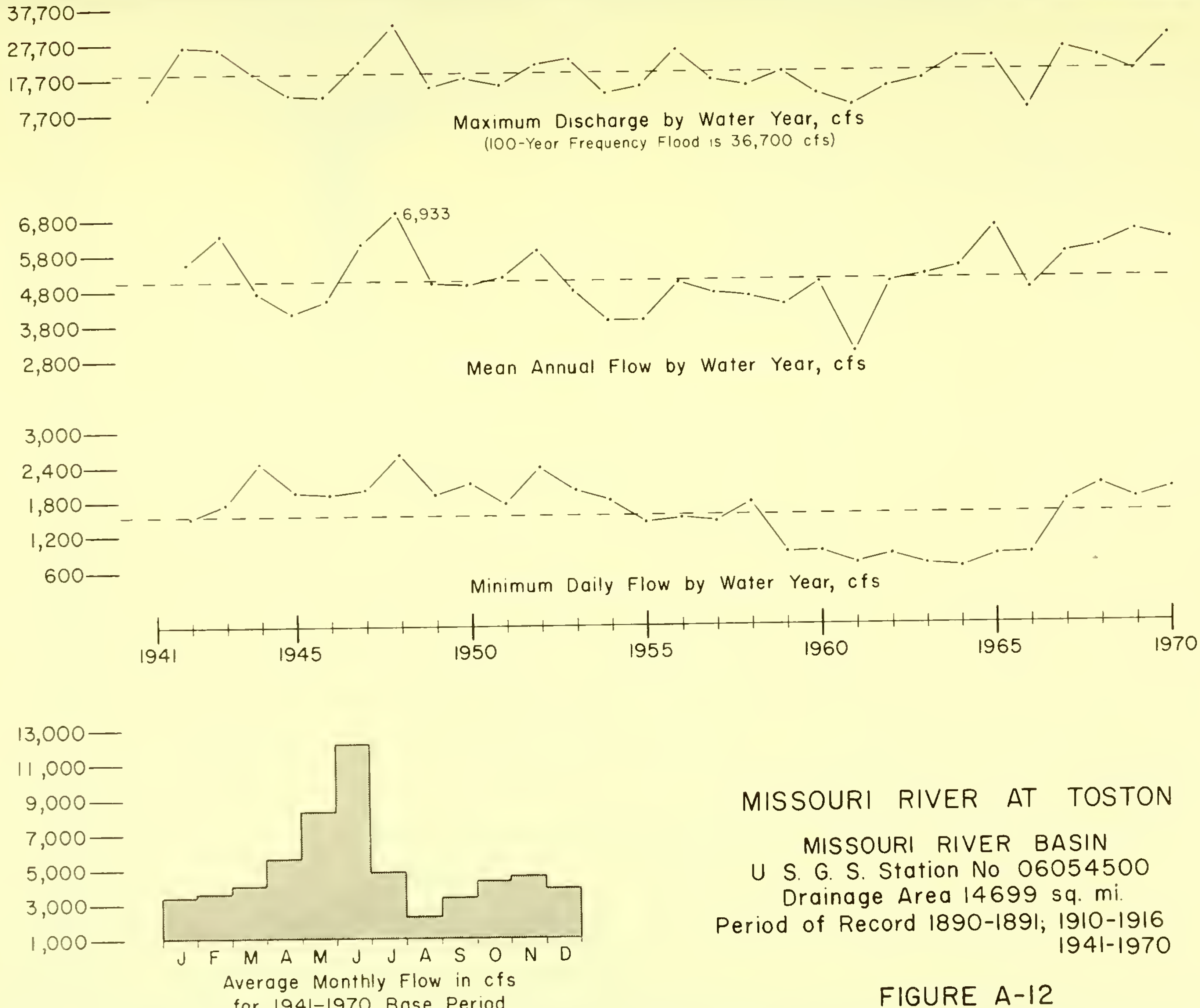
FIGURE A-10



GALLATIN RIVER AT LOGAN

MISSOURI RIVER BASIN
U. S. G. S. Station No. 06052500
Drainage Area 1795 sq. mi.
Period of Record 1893-1895
1928-1970

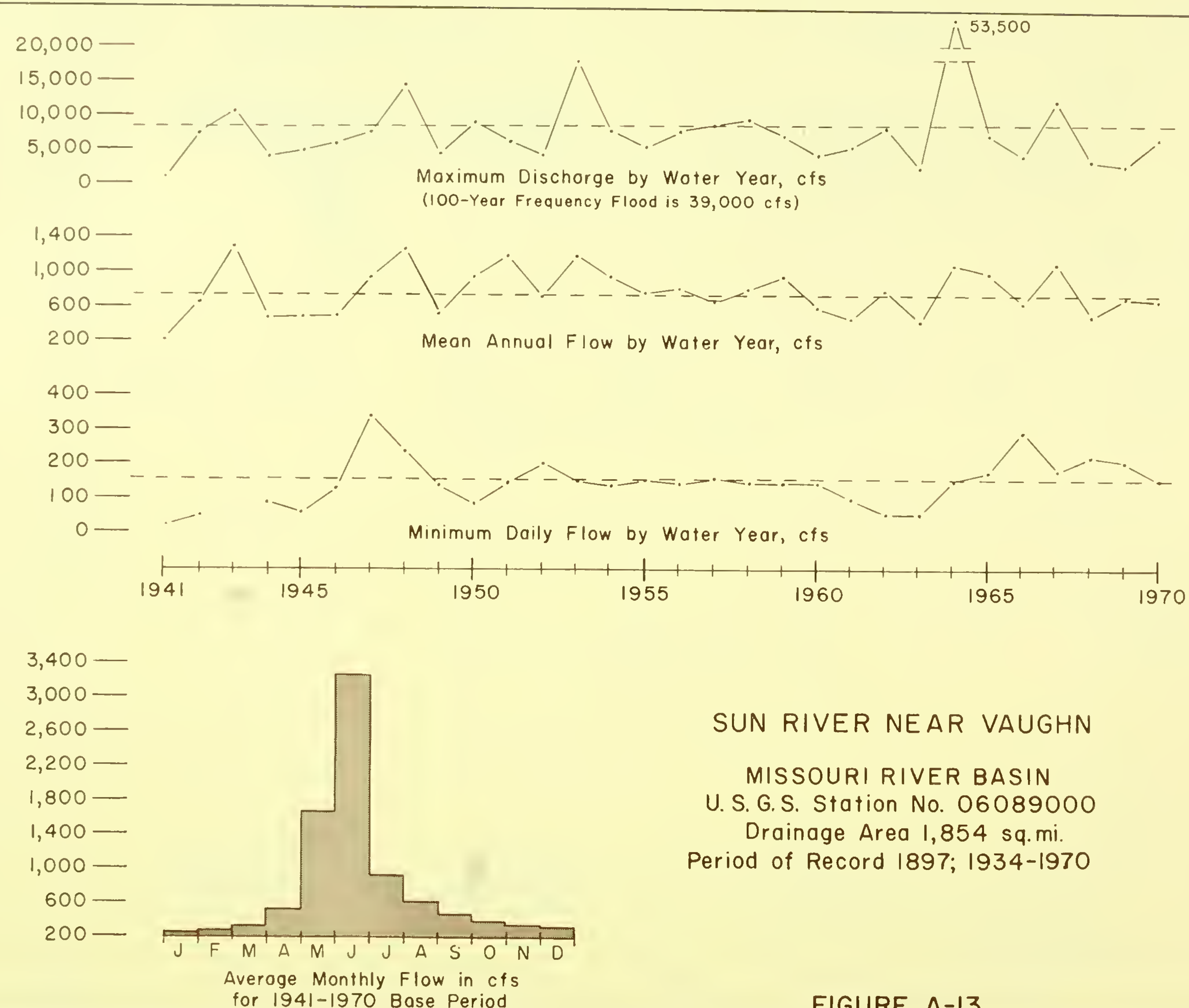
FIGURE A-11



MISSOURI RIVER AT TOSTON

MISSOURI RIVER BASIN
U S. G. S. Station No 06054500
Drainage Area 14699 sq. mi.
Period of Record 1890-1891; 1910-1916
1941-1970

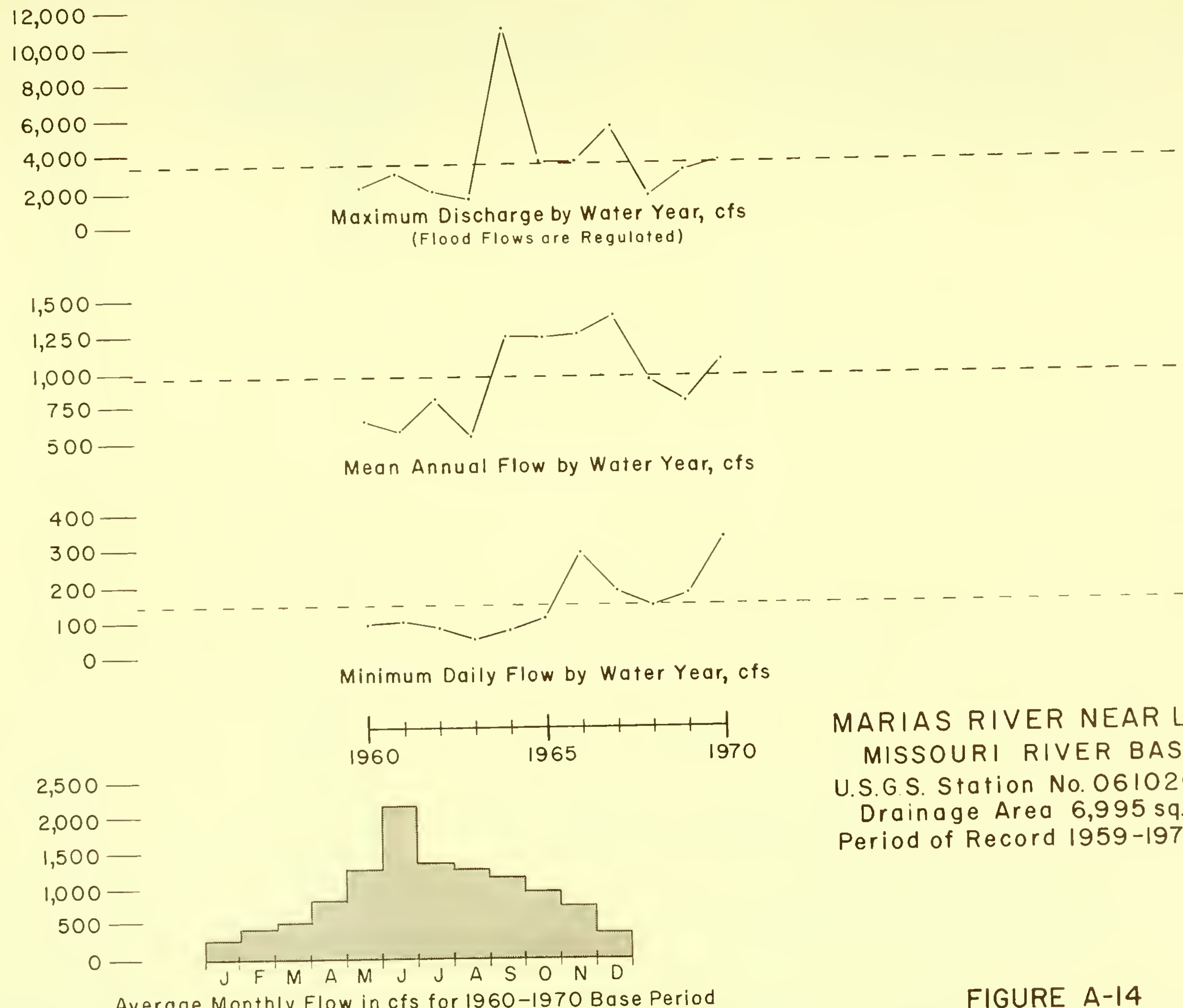
FIGURE A-12



SUN RIVER NEAR VAUGHN

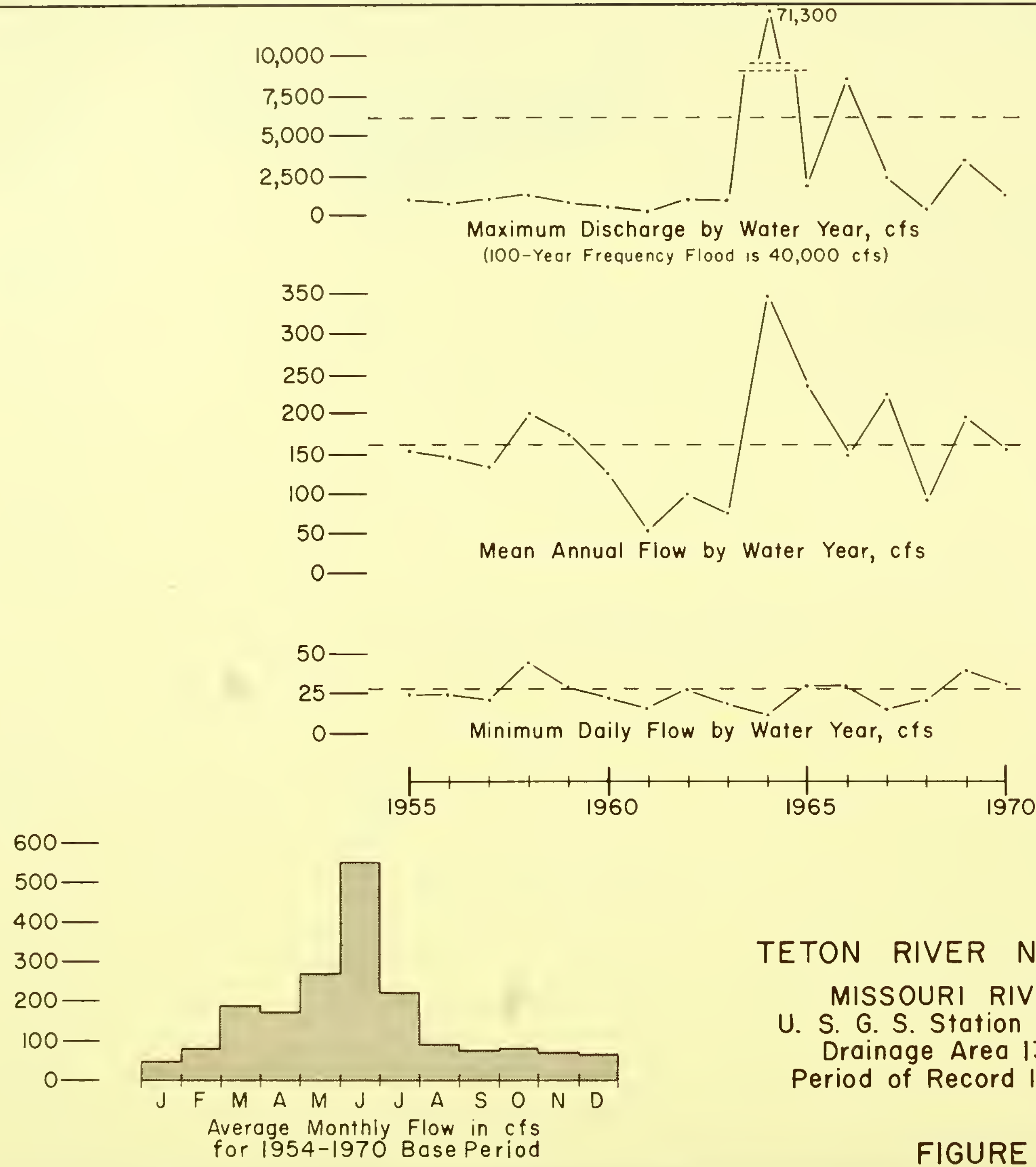
MISSOURI RIVER BASIN
U. S. G. S. Station No. 06089000
Drainage Area 1,854 sq. mi.
Period of Record 1897; 1934-1970

FIGURE A-13



MARIAS RIVER NEAR LOMA
MISSOURI RIVER BASIN
U.S.G.S. Station No. 06102050
Drainage Area 6,995 sq. mi
Period of Record 1959-1970

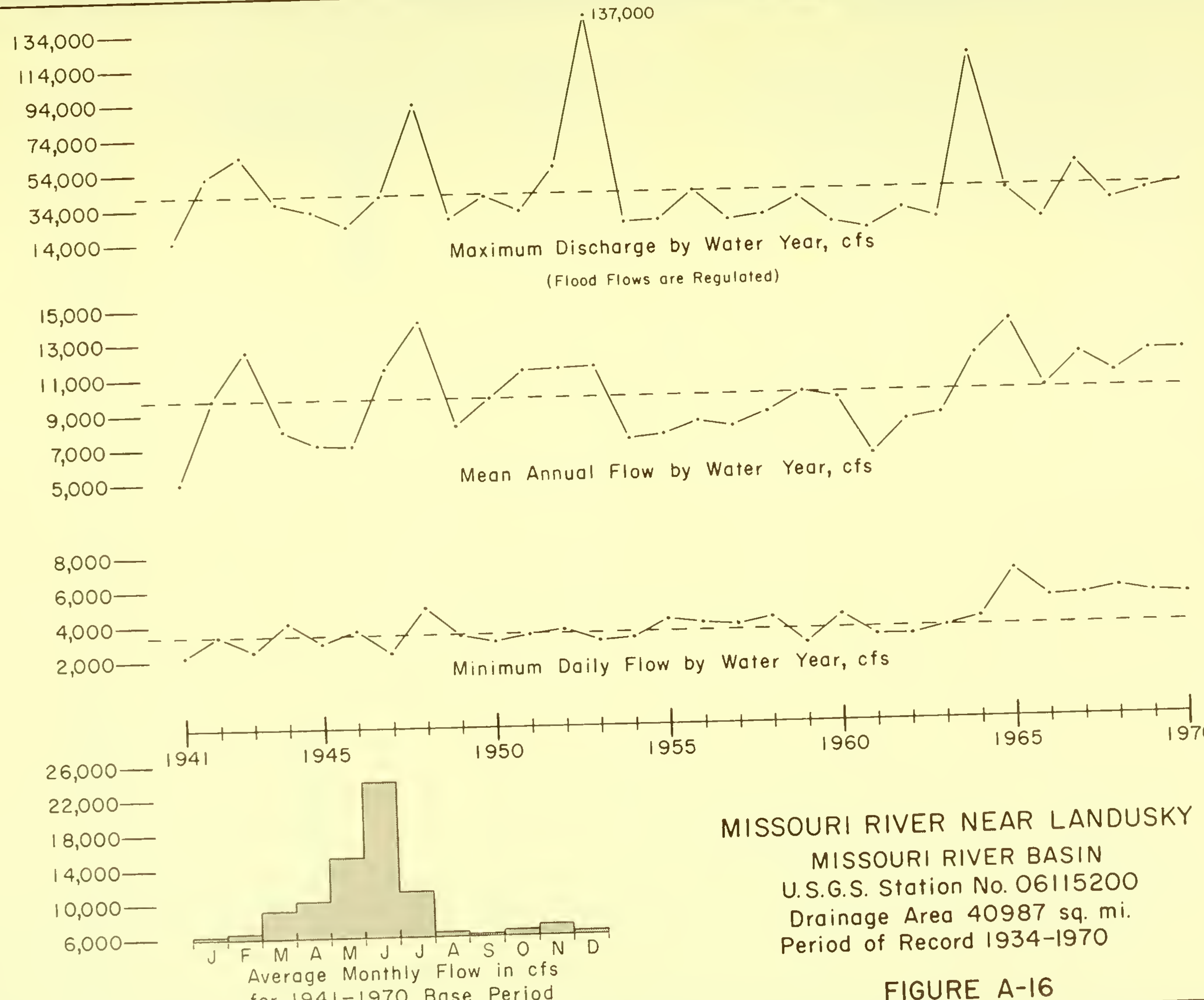
FIGURE A-14



TETON RIVER NEAR DUTTON

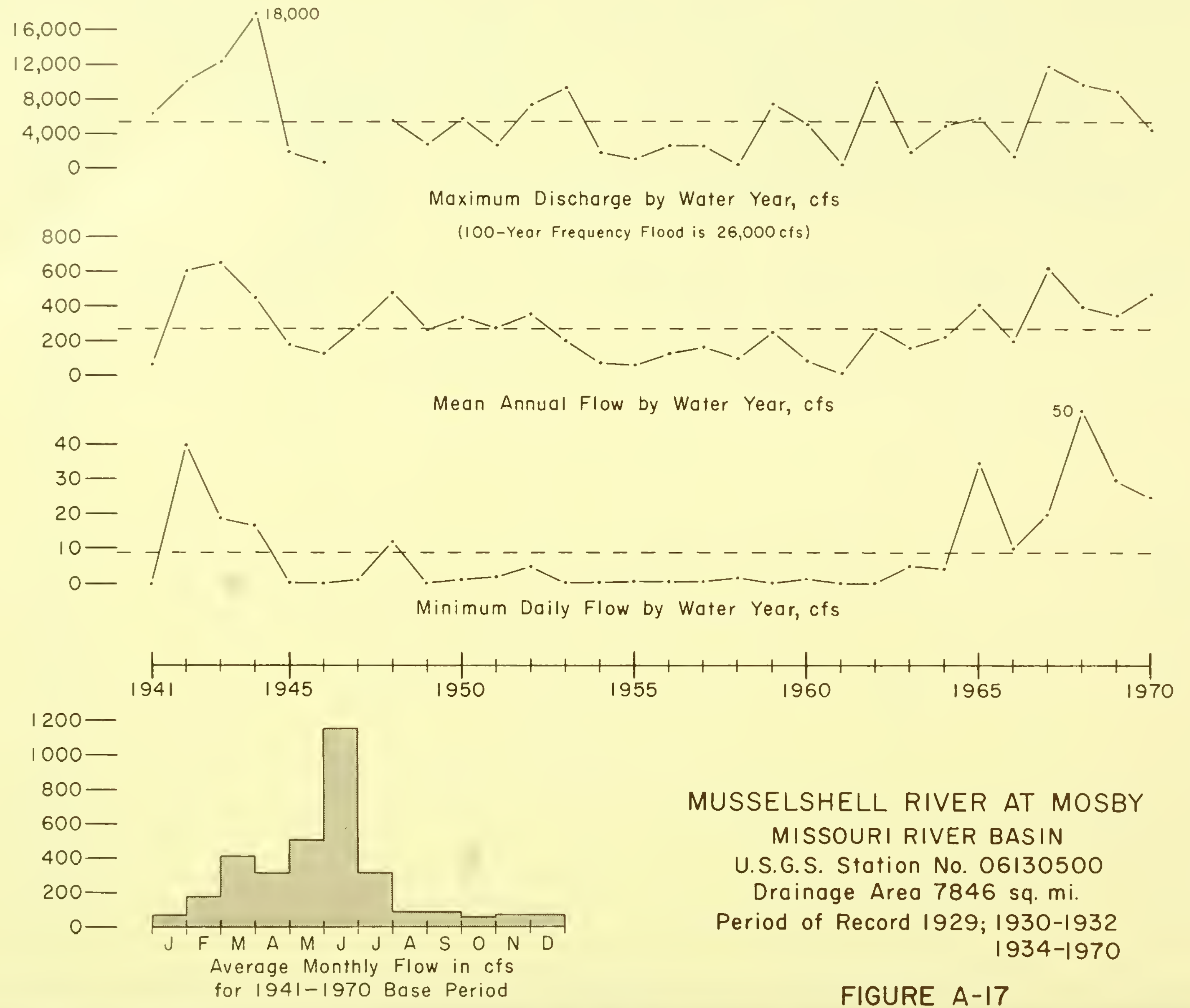
MISSOURI RIVER BASIN
U. S. G. S. Station No. 06108000
Drainage Area 1308 sq. mi.
Period of Record 1954-1970

FIGURE A-15



MISSOURI RIVER NEAR LANDUSKY
MISSOURI RIVER BASIN
U.S.G.S. Station No. 06115200
Drainage Area 40987 sq. mi.
Period of Record 1934-1970

FIGURE A-16



MUSSELSHELL RIVER AT MOSBY

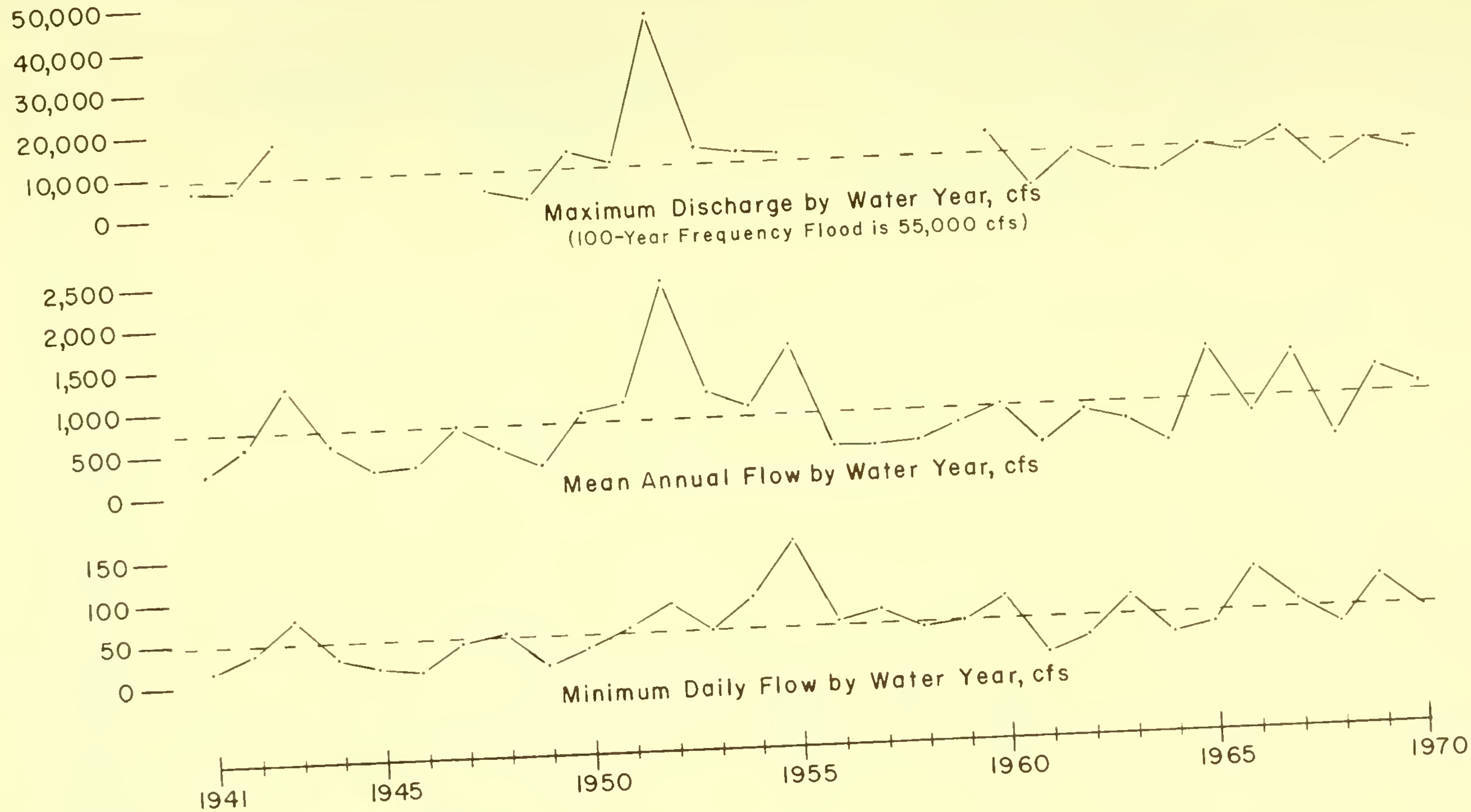
MISSOURI RIVER BASIN

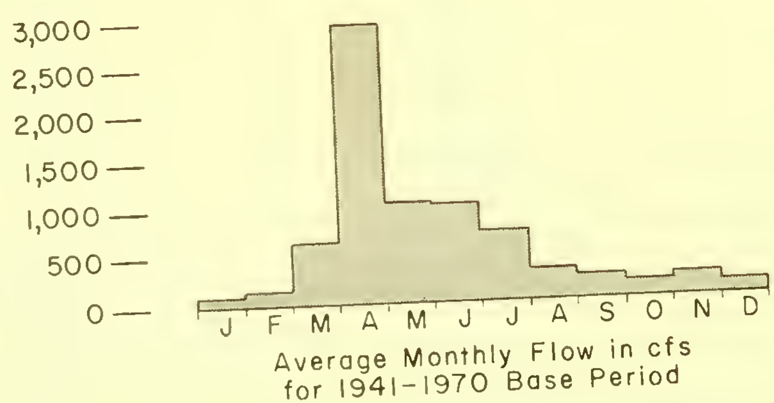
U.S.G.S. Station No. 06130500

Drainage Area 7846 sq. mi.

Period of Record 1929; 1930-1932
1934-1970

FIGURE A-17

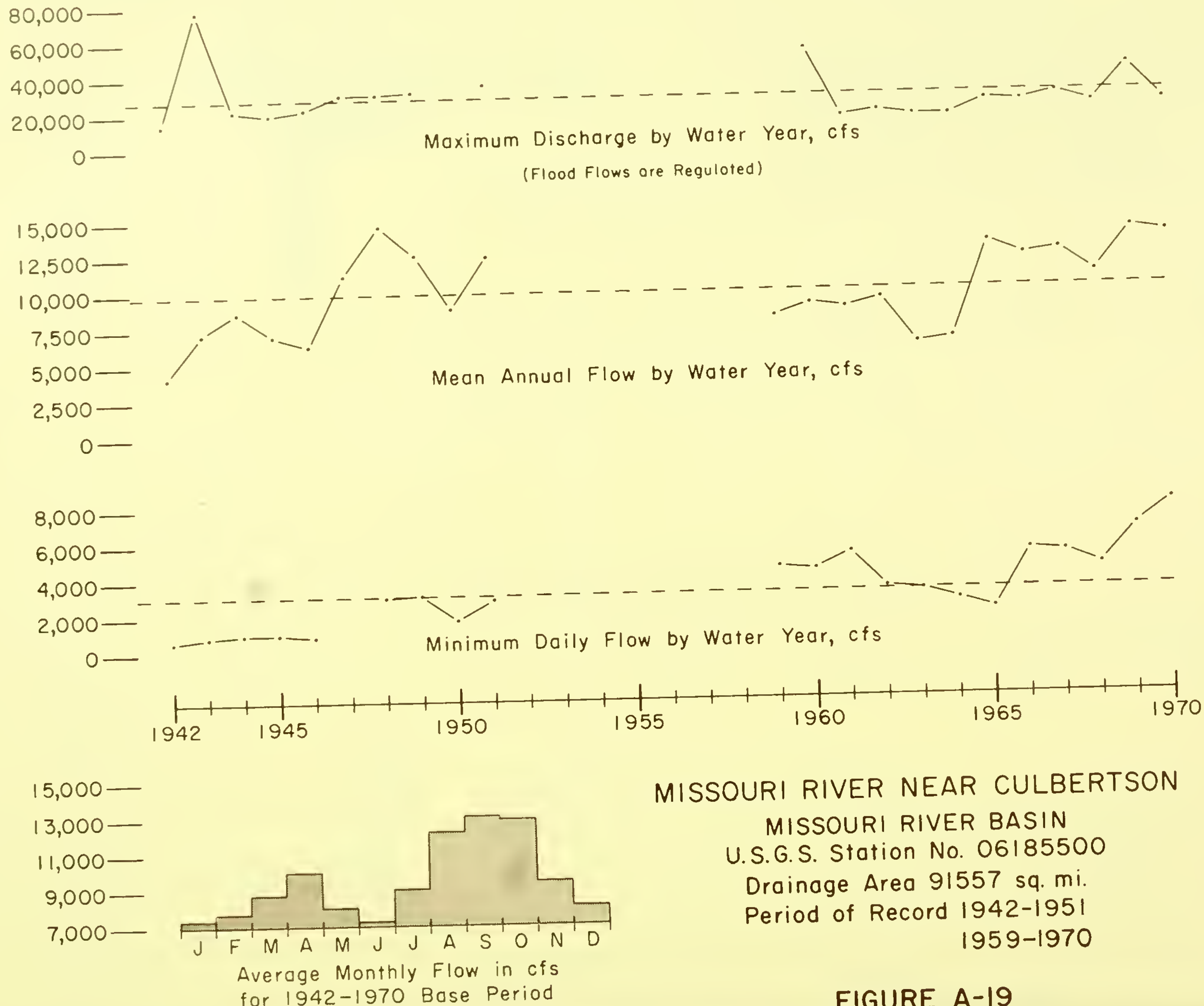




MILK RIVER AT NASHUA

MISSOURI RIVER BASIN
U.S.G.S. Station No. 06174500
Drainage Area 22,332 sq. mi.
Period of Record 1939-1970

FIGURE A-18



MISSOURI RIVER NEAR CULBERTSON

MISSOURI RIVER BASIN

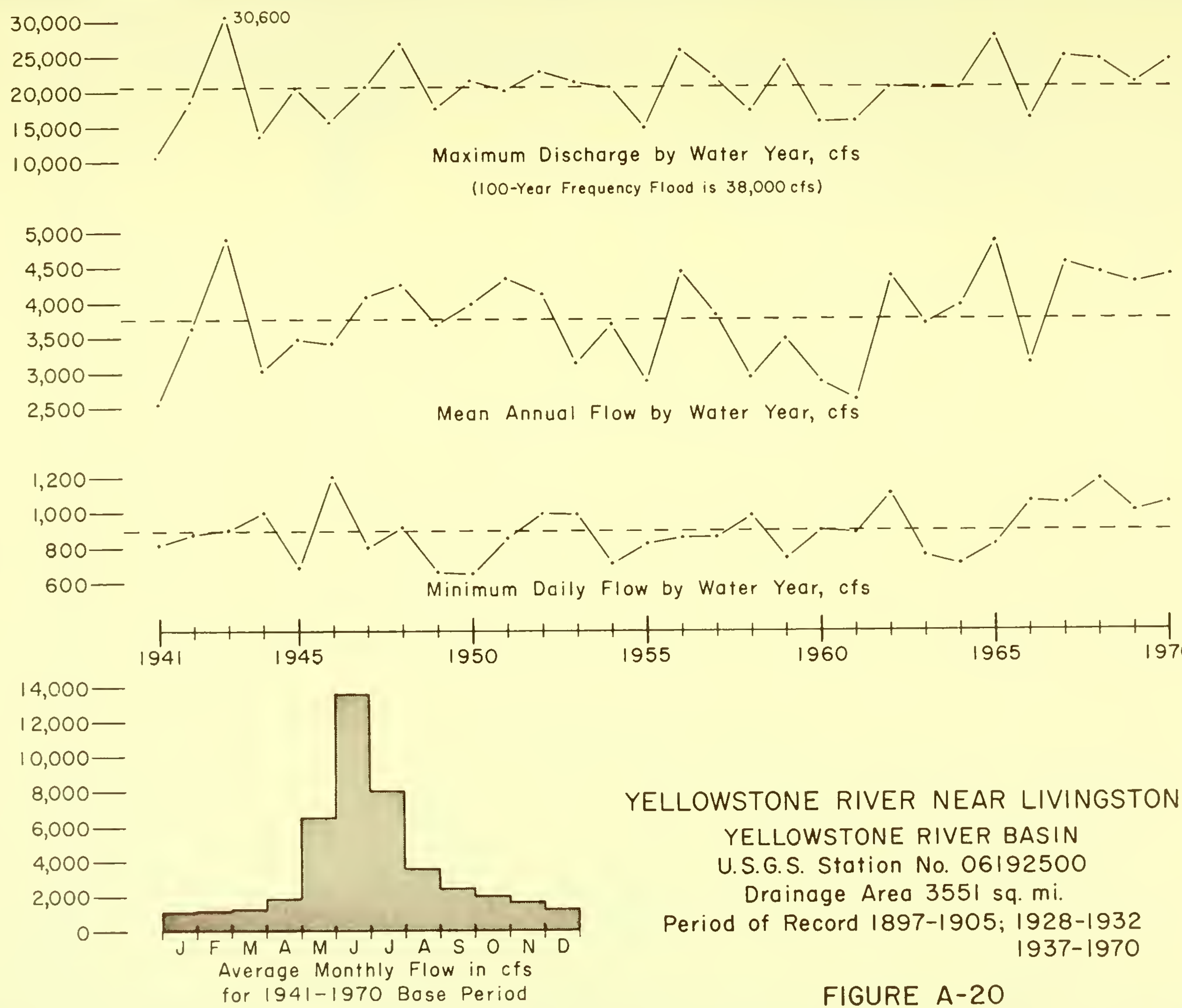
U.S.G.S. Station No. 06185500

Drainage Area 91557 sq. mi.

Period of Record 1942-1951

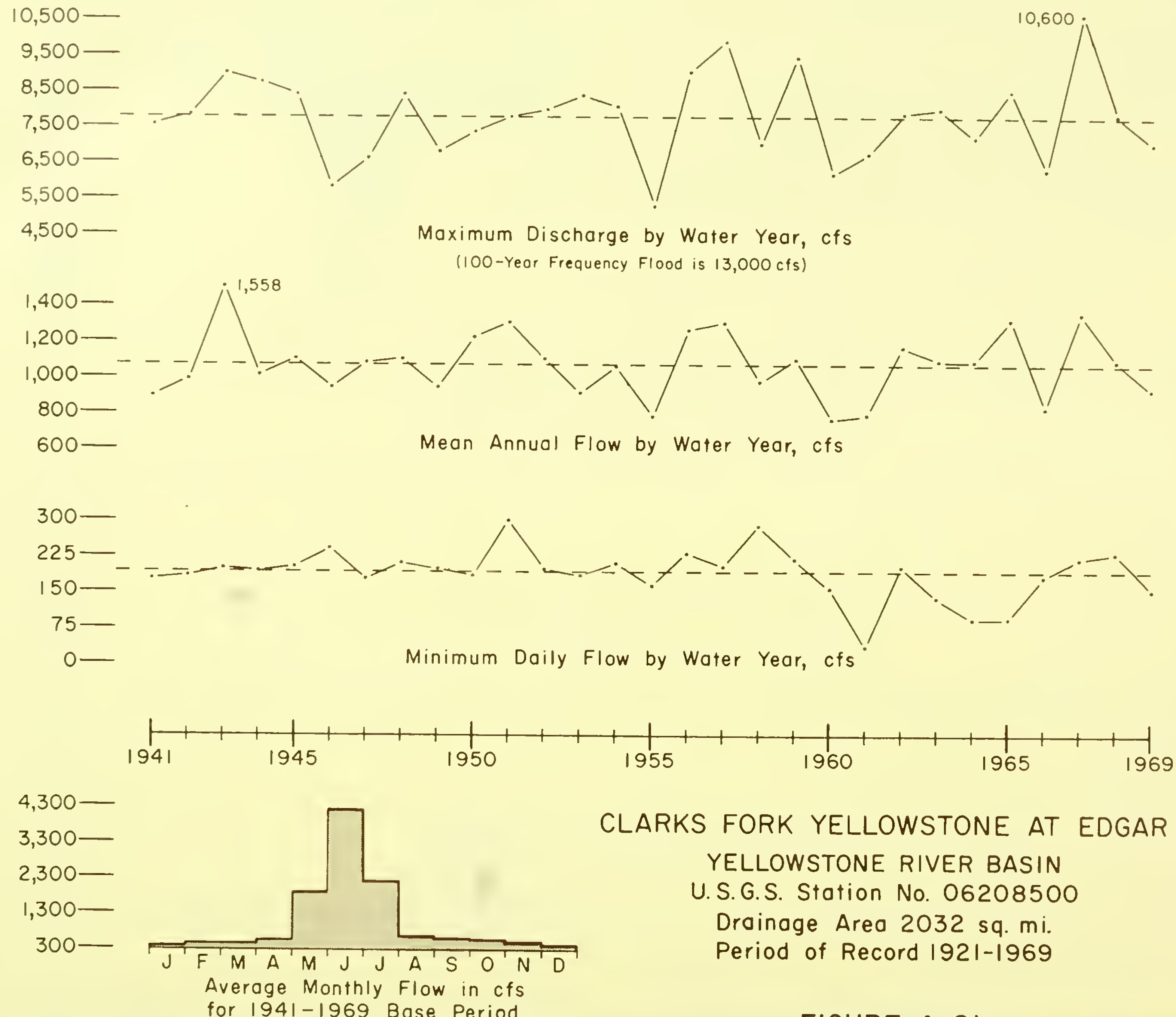
1959-1970

FIGURE A-19



YELLOWSTONE RIVER NEAR LIVINGSTON
YELLOWSTONE RIVER BASIN
U.S.G.S. Station No. 06192500
Drainage Area 3551 sq. mi.
Period of Record 1897-1905; 1928-1932
1937-1970

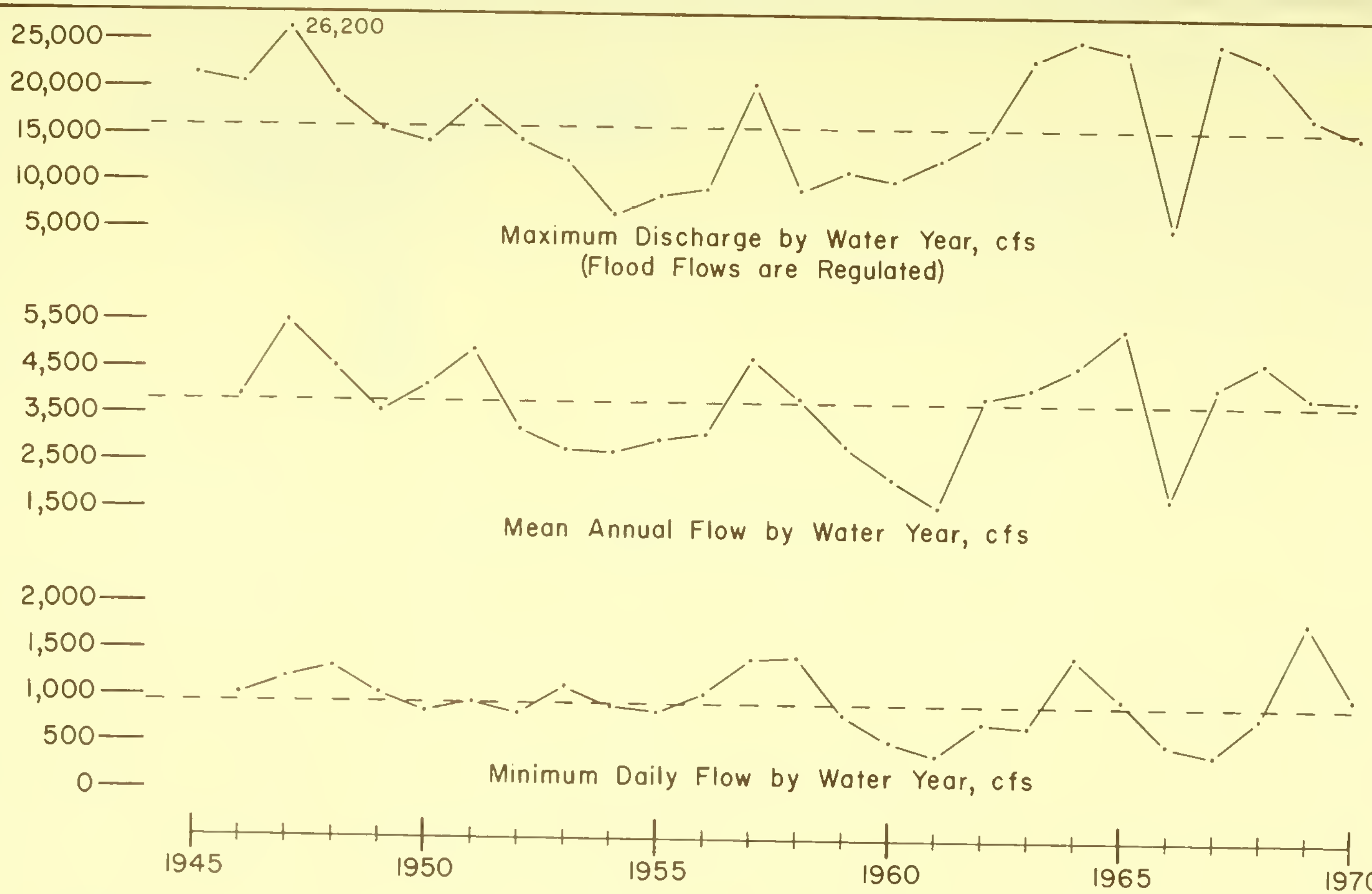
FIGURE A-20

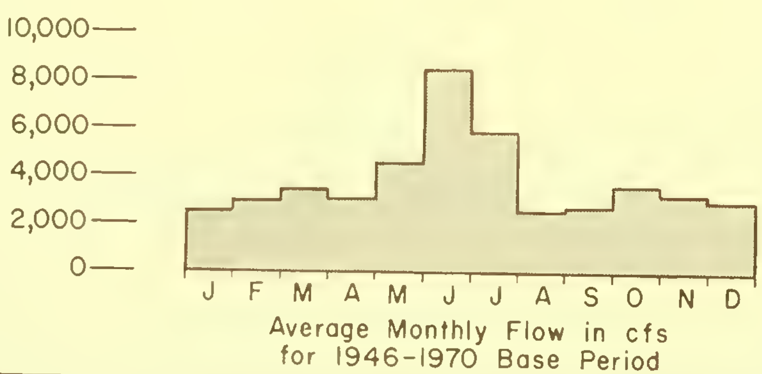


CLARKS FORK YELLOWSTONE AT EDGAR

YELLOWSTONE RIVER BASIN
U.S.G.S. Station No. 06208500
Drainage Area 2032 sq. mi.
Period of Record 1921-1969

FIGURE A-21

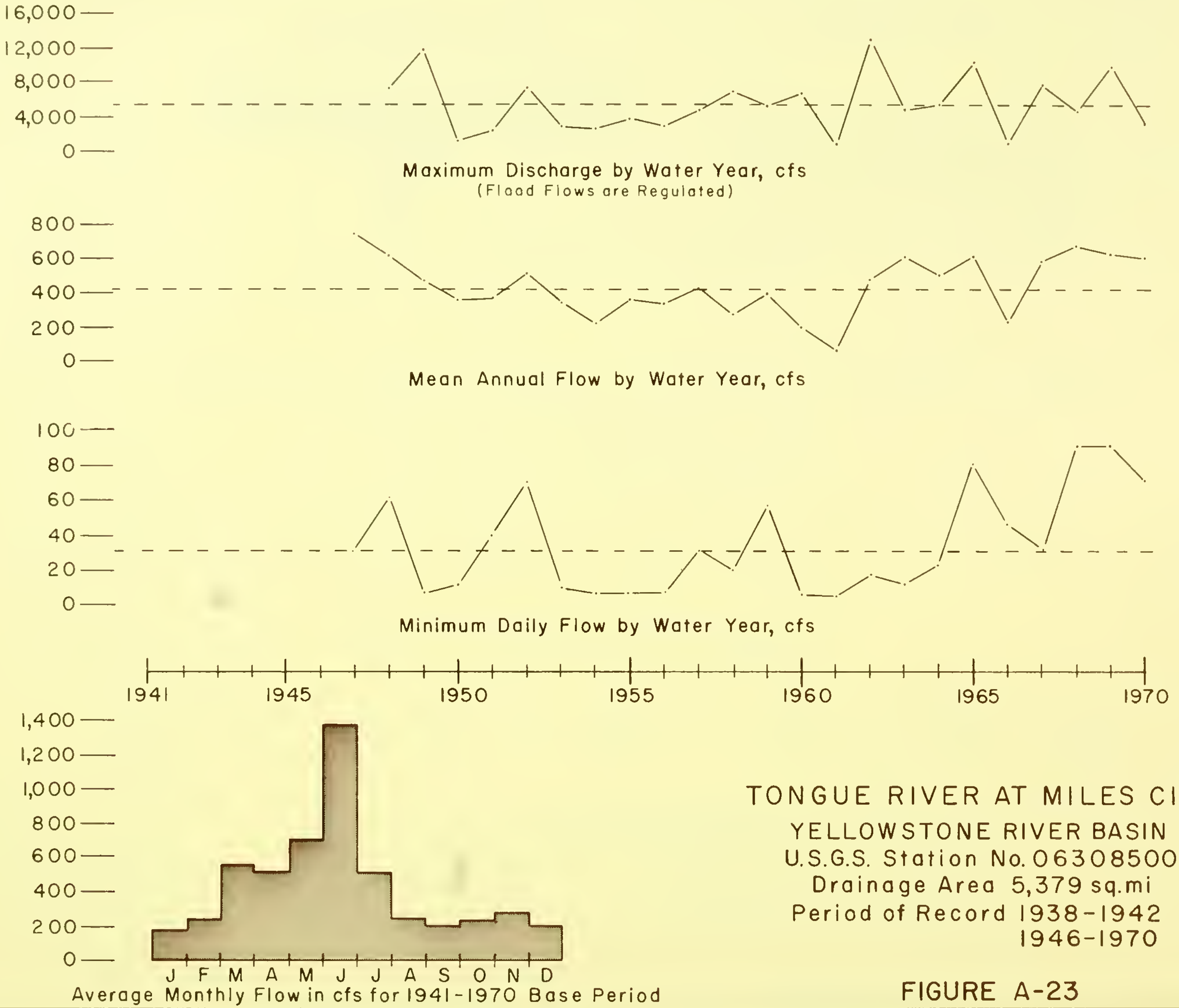




BIGHORN RIVER AT BIGHORN

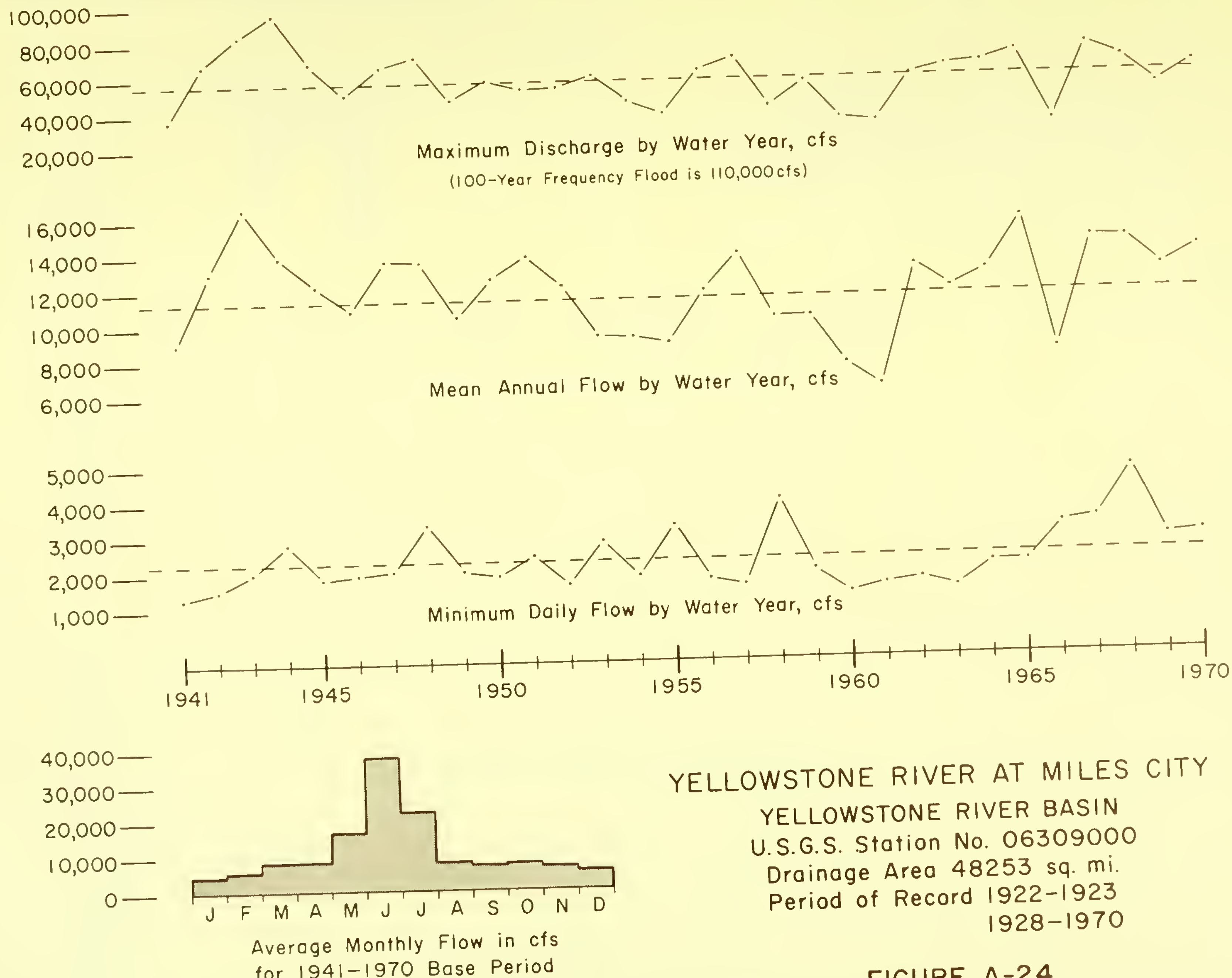
YELLOWSTONE RIVER BASIN
U. S. G. S. Station No. 06294700
Drainage Area 22885 sq. mi.
Period of Record 1945-1970

FIGURE A-22



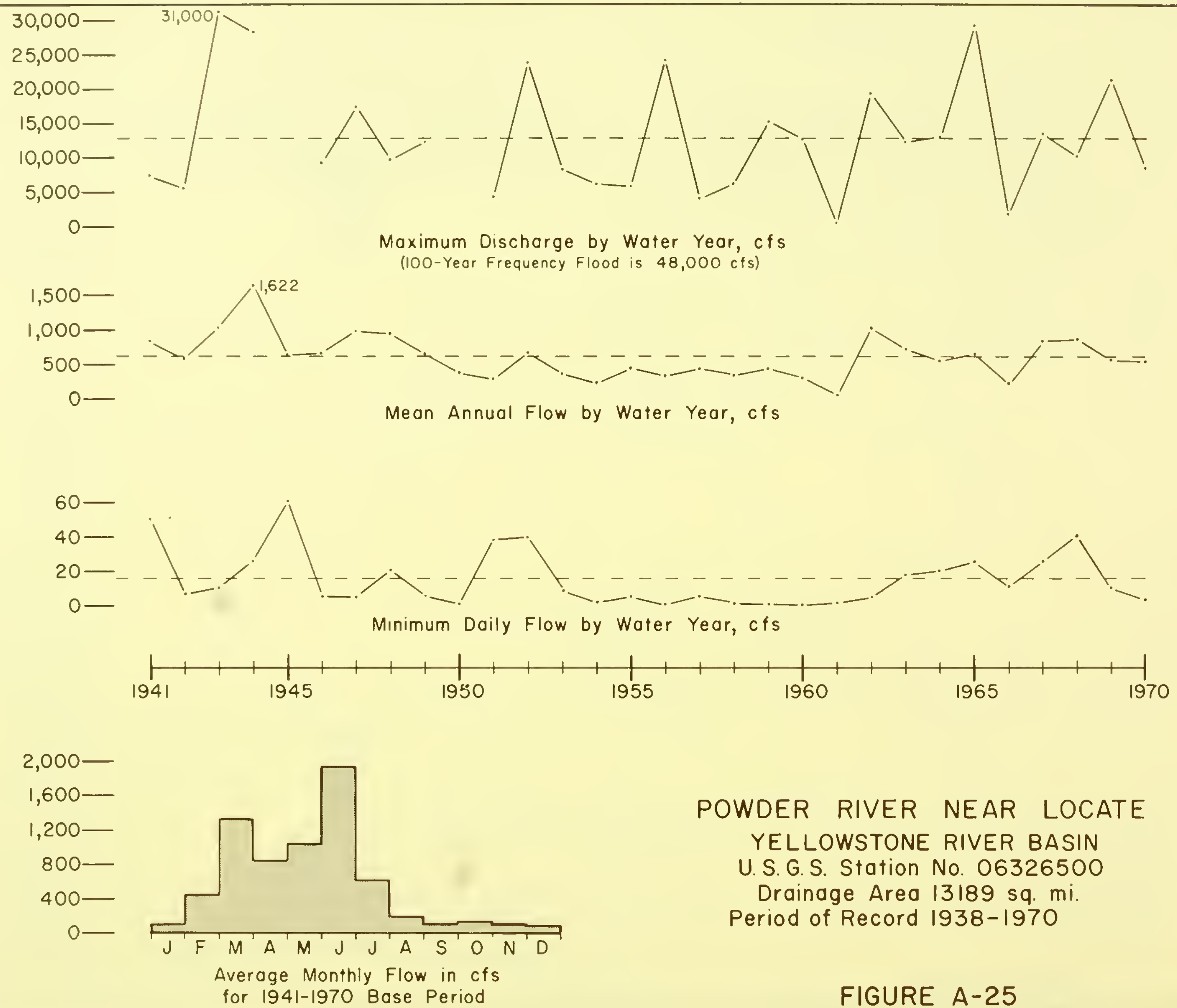
TONGUE RIVER AT MILES CITY
YELLOWSTONE RIVER BASIN
U.S.G.S. Station No. 06308500
Drainage Area 5,379 sq.mi
Period of Record 1938-1942
1946-1970

FIGURE A-23



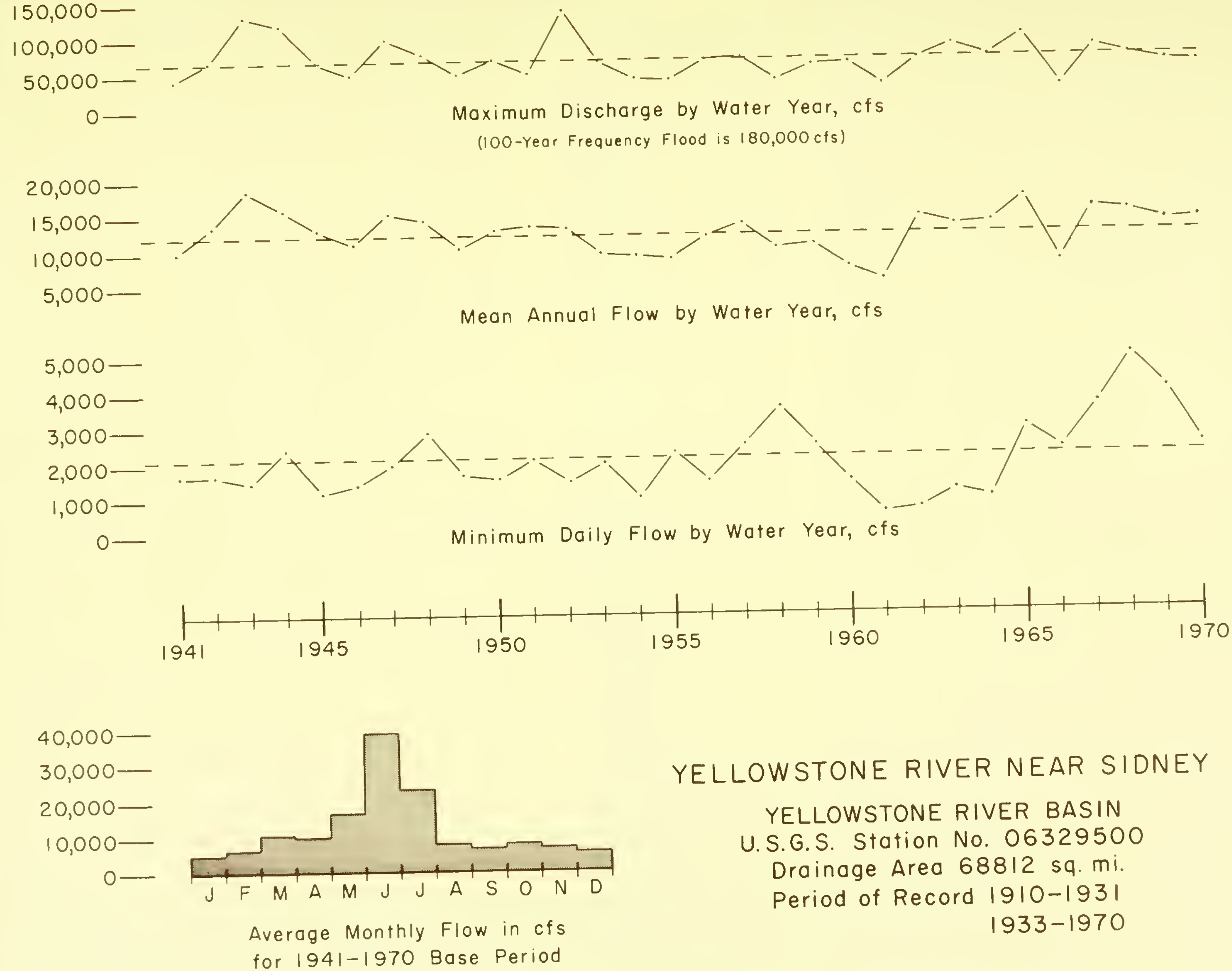
YELLOWSTONE RIVER AT MILES CITY
YELLOWSTONE RIVER BASIN
U.S.G.S. Station No. 06309000
Drainage Area 48253 sq. mi.
Period of Record 1922–1923
1928–1970

FIGURE A-24



POWDER RIVER NEAR LOCATE
YELLOWSTONE RIVER BASIN
U.S.G.S. Station No. 06326500
Drainage Area 13189 sq. mi.
Period of Record 1938-1970

FIGURE A-25



YELLOWSTONE RIVER NEAR SIDNEY

YELLOWSTONE RIVER BASIN
U.S.G.S. Station No. 06329500
Drainage Area 68812 sq. mi.
Period of Record 1910-1931
1933-1970

FIGURE A-26

REFERENCE MATERIALS

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GLOSSARY

Acre
A unit of land containing 4,840 square yards (43,560 square feet).

Acre-foot
Enough water to cover one acre to a depth of one foot. This amount is equal to 43,560 cubic feet or 325,900 gallons.

Alluvium
Material deposited gradually by moving water.

Annual yield
The supply of water produced by a stream or watershed over a one-year period.

Aqueduct
A conduit or lined canal designed to transfer water from one point to another.

Aquifer
Water-bearing rocks or formations.

Artesian well
A well wherein the pressure of the strata is so great that it forces the water to the surface.

Channelization
The confining of a stream to a man-made channel.

Continental
Describes a climate characterized by low surface humidity, large diurnal temperature variations and pronounced temperature extremes, light but variable precipitation confined primarily to warmer seasons, and moderate prevailing wind speeds.

Cubic feet per second (cfs)
A measure of flow equal to 448.8 gallons per minute or 40 Montana miner's inches.

Diversion
The taking of water from a water body by means of a canal, pipe, ditch, or other direct means

Drainage area
See **watershed**.

Ephermeral stream
See **intermittent stream**.

Eutrophication
The process of producing greater amounts of organic matter in a body of water than can be consumed through existing biological oxidation processes. This condition may be caused by natural or artificial fertilization in conjunction with other growth factors.

Evaporation

The process by which a substance changes from the liquid state to the gas or vapor state.

Evapotranspiration

The combination of water loss through evaporation (from soil and surface water bodies) and transpiration (from plants).

Fluvial

Pertaining to a river.

Freeze-free season

The period of the year when the temperature does not drop below 33°F or 1°C.

Glaciation

The modification of the topography by glaciers.

Humidity

The degree of moisture in the atmosphere expressed as a percentage of the atmosphere's capacity.

Hydrology

The science of the behavior of water in the atmosphere, on the earth's surface, and underground.

Impervious Rock

Rock which, being nonporous or practically so, does not allow water to soak into it or pass through it freely.

Indian summer

A period of warm or mild weather late in autumn or in early winter.

Infiltration

The downward entry of water (as into soil).

Intermittent stream

One that carries water only in times of rainfall or runoff, and remains a dry channel during the rest of the year.

Intermontane

Lying between mountains.

Mean annual streamflow

The average yearly flow of a river.

Multiobjective planning

A water-planning approach which deals with the objectives of national economic development, regional development, and environmental quality.

Multipurpose project

A project designed to serve more than one purpose; for example, one which provides irrigation, flood control, recreation, and hydroelectric power.

Nutrient

Anything which promotes growth or provides nourishment.

Per capita

Per person.

Perennial stream

A stream that carries water throughout the year, as opposed to an intermittent stream.

Permeable rock
: Rock, either porous or fissured, that allows water to soak into it and pass through it freely.

Physiography
: Physical geography; a description of the natural features of the surface of the earth.

Porosity
: The capacity of rock or soil to hold water, usually expressed as the percentage of the soil or rock volume not occupied by soil or rock particles.

Precipitation
: Any form of water, whether liquid or solid, that falls to the ground from the atmosphere.

Recharge area
: An area in which an aquifer receives water by force of gravity; usually where a permeable layer lies close to the surface.

Relative humidity
: The ratio of the amount of water vapor actually present in the air to the greatest amount possible at the same temperature.

Return flow
: Diverted water which is not consumed and returns to a surface or ground-water body.

Riprap
: A foundation or sustaining wall of stones put together without order.

Runoff
: That portion of rainfall or melted snow which ultimately reaches a surface stream.

Sedimentary
: Formed by deposition or accretion of grains or fragments of rock-making materials. Applied to all kinds of deposits from the waters of streams, lakes, or seas and in a more general sense to deposits of wind and ice.

Sedimentation
: The process of deposition of materials from suspension in water of streams, lakes, and seas, or from the action of wind or ice.

Semi-maritime
: Describes a climate reflecting modified Pacific air mass characteristics, including milder winters, cooler summers, a more even annual distribution of precipitation, higher humidity, more cloudiness in all seasons, and lighter winds than those associated with continental climates.

Semi-Pacific
: See **semi-maritime.**

Sheet erosion
: The removal of a fairly uniform layer of soils or materials from the land surface by the action of rainfall or runoff water.

Stratification
: The layering of sediments into beds, or strata.

Thermal
: Hot or warm. Often used to describe water heated by natural means.

Topography
: The configuration of a surface, its relief, and the position of its natural and man-made figures.

Total dissolved solids

Minerals and other solids which form a residue after evaporation of water.

Transpiration

The emission of water vapor from the surface of plant parts.

Tributary

A stream that discharges its waters to a larger stream.

Watershed

The area from which water drains to a single point; in a natural basin, the area contributing flow to a given point on a stream (drainage area).

Water table

The top of the zone of saturation in which all rocks are saturated with water.

Montana
Department of Natural Resources
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